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COMMERCIAL AND FINANCIAL ASPECTS OF THE GAS INDUSTRY.[1]

BY

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MR. CHAIRMAN, LADIES AND GENTLEMEN:

At the outset of my remarks I feel that I should say a word in appreciation of the initiative and energy that have made possible this series of lectures; and I welcome the opportunity to join with those who recognize the public spirit of the individuals and associations who have contributed to the success of the celebration.

HISTORICAL.

About one hundred years ago, two of the leading nations of Europe brought forth independently of each other an invention

[1] Lecture delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant under the auspices of the American Philosophical Society, the Franklin Institute, the American Chemical Society, the American Gas Institute, in the hall of The Franklin Institute, Philadelphia, on Friday, April 19, 1912.

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which was destined to become a factor mightier than almost any other for the promotion of human comfort, for advancing civilization, and for giving employment to great industrial armies.

On this occasion, therefore, we celebrate the birth of a great industry; and it is fitting that we recall the names of those patient pioneers whose struggles are a matter of history, and whose subtle creation illumines the civilized world. Among the names which we honor to-day are Van Helmont Clayton, Murdoch, Lebon, Clegg and Winsor, but it is generally conceded that to William Murdock belongs the credit of being the first to develop the gas industry along practical lighting lines.

From Murdoch's own account we learn that in 1798 he removed from Cornwall, where he had conducted important experiments, lighting his own house (1792), to Boulton, Watt & Company's works for the manufacture of steam engines at the Soho Foundry, near Birmingham, where he constructed an apparatus on a large scale which was applied to the lighting of the principal building. His experiments were continued with some interruption until the year 1802, when a public display of the light was made in the illumination of the manufactory at Soho, on the occasion of the celebration of the Peace of Amiens. A contemporary writer states "This remarkable illumination was the first public display (of gas-lighting) in this country and at the time produced a very strong impression upon the inhabitants of the town. The illumination of Soho works on this occasion was one of extraordinary splendor. The whole front of that extensive range of buildings was ornamented with a great variety of devices, that admirably displayed many of the varied forms of which gas light was susceptible."

Murdoch's efforts were stimulated by news of the activities of M. Lebon, of Paris, along similar lines. This is related in a letter addressed to Soho from which Dr. Henry published the following extract: "I don't know exactly what time the first trials were made or published in France. The first notice we received of them here was in a letter from a friend at Paris dated November 8, 1801, in which he desired me to inform Mr. Murdoch that a person had lighted up his house and gardens with the gas obtained from wood and coal and had in contemplation to light up the city of Paris."

The testimony of James Watt, Jr. (son of the great inven-

tor), who was associated with Matthew Boulton in the firm of Boulton & Watt, proprietors of the Soho Works, shows, to use his own words, that "at the period when the peace took place, which, I believe was in the spring of 1802, public display of these lights was made in the illumination of Mr. Boulton's manufactory, which then took place. In 1803 we erected an apparatus for the purpose of giving a light to a part of our own works and till 1804 we continued making experiments on the gas produced and also on the different coals out of which the gas was to be made; on the manner of making the retorts best adapted to the purpose; upon the materials and construction of the pipes; upon the size and construction of the gasometers; upon the economy of the different sorts of burners, etc. The experiments were very long and attended with a great deal of expense. We were out of pocket £4,000 or £5,000 and are so at this moment for the experiments and machinery."

In Hunt's "History of the Introduction of Gas Lighting," we are told that:

> "It was the fear of being anticipated by Lebon that quickened the firm's pace and finally overcame their reluctance to embark in this new venture. Without Lebon, therefore, Murdoch's invention might have remained indefinitely in the background: but, it may be with equal justice be said that without Murdoch, Lebon's ideal could not have been realized. There is no evidence that either Murdoch or Lebon aimed at anything beyond a number of separate and independent installations; but Lebon's idea of 'lighting a part of Paris with it' seems to have fired the imagination of his follower, Winsor, in whose hands a public supply of gas lighting became a reality, although this was only made practicable by the achievements of Murdoch and the development of engineering and industrial art."

Lebon was granted a patent for a term of 15 years from September 28, 1799, as shown by the records in the Patent Office at Paris.

Frederick A. Winsor, contemporary of Murdoch and Lebon, is described as a man of little experience but possessed of an extremely sanguine temperament and unbounded imagination, combined with determination and ingenuity. He was the first to advocate publicly the distribution of gas from a central source, and was the promoter of the first chartered gas light company. The London press spoke of him most disparagingly and described his scheme of gas lighting as "wild, absurd and extrava-

gant in its conception and fraught with the greatest danger in its execution," and alluded to Winsor's proposal for "enlightening the inhabitants of London" as "fire of wind." Winsor was himself responsible for much of this opposition by reason of his extravagant statements as to profits (as much as one thousand per cent. being promised) of the venture. Indeed a perusal of his flowery prospectus would give pause even to the modern advertising man, and the circus poster in its palmiest days hardly approached its flights. For instance, in one of his pamphlets, after claiming such utilities as "tanning skins," "smoking bacon and hams," and "fixing color in dyeing," he says, "as to illuminations, they may be carried on to the utmost extent of beauty and variegated fancy, by this docile flame, which will play in all forms, submit to instant changes, ascend in columns to the clouds, descend in showers from the trees, walls, etc., arise from the water, and even in the same pipe with a playing fountain. The constant varying of the flame in rooms and gardens between flaming pyramids, festoons, garlands, roses, flambeaux, etc., afford the spectator a most delightful sight, cherish the soul and create good humor by uniting convenience, utility and pleasure."

In 1803 and 1804 Winsor publicly exhibited his system of illumination by coal gas at the Lyceum Theatre, London. He showed the manner of conveying the gas to different parts of the house, and by the use of various kinds of burners he was enabled to display something of that variety of form which may be given to the flame. His exhibitions proved that the intensity of coal gas rendered it less liable to be extinguished by strong and sudden gusts of wind, and he also showed that if properly managed the burning of it would not produce smoke or throw out sparks such as often fly from the burning wicks of lamps or candles, a circumstance which rendered gas a desirable kind of light, as being less dangerous in its use than either of the other forms. Afterwards Winsor moved his exhibitions to Pall Mall where early in 1807 he lighted up a part of one side of a street, which was the first instance of this kind of light being applied to such a purpose, and to him therefore belongs the credit of initiating the system of public gas lighting.

As the projector of the National Light & Heat Company Winsor is stated to have raised nearly £50,000 by subscription

for this purpose, all of which, however, was squandered upon commercially unproductive experiments.

In 1809 Winsor projected a new Light and Heat Company and applied to Parliament for an act to incorporate it. This is an important fact in the history of the gas industry, for it was the foundation of the London & Westminster Chartered Gas-Light & Coke Company. The capital proposed to be raised at this time was £200,000. The persons who applied for the act had many difficulties to combat arising both from interest and prejudice. Their projects were represented as visionary and the execution of them fraught with considerable danger. On this occasion they were opposed by Mr. Murdoch on the ground of his priority of right to the discovery. The application terminated unsuccessfully partly because of the unfavorable impressions produced by Winsor's extravagant claims. Murdoch's opposition to Winsor resulted in Parliament protecting the appliance manufacturers against possible competition by the lighting company.

In 1810 another application was made to Parliament by the same parties and though it met with some opposition an act was passed authorizing His Majesty to grant them a charter within three years from the time of passing the act.

Thus Winsor's plan of a National Light and Coke Company was in part accomplished by the formation of a local gas-light and coke company. The incorporation of this company, which occurred in April, 1812, the centenary of which we celebrate, was an important step in the direction of placing the new industry upon a basis that promised its permanent establishment and increased the probability of its ultimate success. Experience had already proved that the resources of the individual were inadequate to cope successfully with undertakings of such magnitude and cost. From calculations as well as from actual surveys that were made it appeared that the expense of laying down pipes for the city of Westminster alone would be £150,000 without including any other expense.

In 1813 Westminster Bridge was lighted with gas. About this time, the City of London Gas-Light Company was established, and two others were projected for the metropolis, one of them in Southwark and the other in the eastern district.

From the time of the formation of the Chartered Gas-Light

and Coke Company to the year 1813, experiments had been carried on by Messrs. Winsor, Accum & Hargraves, at which time the company was almost on the point of dissolution.

Samuel Clegg was engaged as engineer of the Company, he having been educated as an engineer in Boulton & Watt's foundry, at which time his attention was first directed to the practicability of distilling gas from coal when assisting in the illumination of the Soho manufactory.

In 1815 Clegg invented and patented the gas meter and governor. The first meter consisted of two large bladders filled alternately with gas and contained in two cases weighted to a certain pressure, the valves being sealed with quick-silver.

Though credit for the original invention and construction of the gas meter belongs to Clegg it has been very materially improved by Samuel Crosley and John Malam.

It is to the introduction of this simple instrument, now in universal use, that a great deal of the success of gas-lighting must be attributed.

Thus Mr. Clegg seems to have been the pioneer in many of the important inventions connected with gas-lighting. Besides the gas meter he introduced the cylindrical gas holder and an automatic pressure regulating device. It is he also who was chiefly responsible for the success of the original Chartered Gas-Light and Coke Company, and he was the first man to commercialize city gas lighting on a large scale.

In 1816 gas had become very common in the City of London.

Paris was first lighted by gas in 1820.

In 1833 the French National Gas Company was projected for lighting Boulogne-Sur-Mer. The capital of £10,000 being too small the Company was taken over by the European Gas Company and capitalized for £200,000 for the purpose of lighting other European towns.

Gas was used at Havre, Caen and Amiens in 1835—at Nantes and Rouen in 1846. The plants for all of these gas works were sent from England.

Before the second London company was chartered our own City of Baltimore granted a charter to the first company to be regularly organized for the purpose of exploiting gas for the illumination of streets and cities in America.

Gas chronology tells us that Baltimore was not only the first city in this country to be lighted with gas, but that it was also the first city in which gas meters were manufactured in the United States, and gives the name of Samuel Hill as the meter maker.

A brief historical summary of gas development in the United States is given in the U. S. census reports for 1900, from which the following is adduced:

The history of the gas industry in this country dates from 1806, at which time David Melville, of Newport, R. I., lighted his premises by means of coal gas which he had manufactured thereon. This took place nine years after the experiments in England. The apparatus as used by Melville was necessarily crude, but underwent improvements from time to time until, in 1813, he secured a patent and later used gas for the lighting of a cotton mill in Watertown, Mass. Gas was also used at about this time in a mill near Providence, R. I., and was employed in 1817 as an illuminant in a light-house. The growth of the industry was at first slow, but with the advances in the details of the construction and operation of gas plants, the improvement and development of special tools and appliances, and the increasing knowledge gained by experience of the laws of physics involved, there came a much more rapid growth. As early as 1816 a company was chartered in Baltimore, Md., followed in 1821 by the formation of a Company in Boston, Mass. New York City adopted gas lighting in 1823 and several years later companies were formed in Brooklyn, N. Y., and Bristol, R. I. New Orleans adopted gas about 1835, twenty-nine years after Melville introduced the new illuminant in this country.

A proposition to light Philadelphia with gas was made in 1803, and a similar one was made in 1817, but both offers were rejected. Repeated efforts were made thereafter looking to the lighting of the city with gas, but it was not until March 21, 1835, that an ordinance was passed providing for the construction of the works. The plant was completed Feb. 8, 1836.

OBJECTIONS RAISED TO THE INTRODUCTION OF GAS.

Like most inventions, gas lighting was not at first taken seriously. It seemed to the American and European world of

1800 to be on a par with the Laputan philosopher's scheme for making sunshine out of cucumbers. People were afraid of this "burning air," as it was called, and could not be convinced that fire or explosion would not be the inevitable result of its general use. When that daring New Yorker, Samuel Leggett, first lighted his house, No. 7 Cherry Street, with gas, people stood at a respectful distance and looked at it much as they might have looked at the witches dancing in Kirk Alloway.

In Europe the prejudice against gas lighting at the time of its introduction was equally strong. Napoleon ridiculed it and said "C'est une grande folie." In 1803, Sir Walter Scott wrote to a friend: "There is a madman proposing to light London with—what do you think? why, with smoke!" Yet Scott himself had Abbotsford piped for gas not many years later. Clegg gives an account of the horrors of the lamp-lighters when they first beheld the burning gas and how he was obliged to light the lamps himself for some time on account of the fears of the people. Even such men as Sir Humphry Davy and Sir Joseph Banks were unable for many years after this to overcome the prejudice which existed in their own minds concerning it and they thought the scheme a wild and dangerous one.

Another concrete instance of this prejudice can be cited right here in Philadelphia. On November 28, 1833, a petition signed by several hundred of the excellent people of this city was addressed to "The Honorable the Select and Common Councils of the City of Philadelphia," protesting against the use of gas, in the following terms:

"GENTLEMEN: The subscribers beg leave respectfully to remonstrate against the plan now in agitation for Lighting the City with Gas, as they consider it a most inexpedient, offensive, and dangerous mode of lighting. In saying this they are fully sustained by the accounts of Explosions, Loss of Life, and great destruction of property, where this mode of lighting has been adopted.

"We consider Gas to be an article as Ignitable as Gunpowder, and nearly as fatal in its effects; as regard the immense destruction of property, we believe the vast number of fires in New York, and other cities, may be in a great measure ascribed to this mode of lighting; the leakage of pipes and carelessness of stopping off the Gas, furnish almost daily instances of its destructive effects. And when we consider that this Powerful and Destructive Agent must necessarily be often left to the care of youth, domestics and careless people, we only wonder that the consequences have

not been more Appalling. It is also an uncertain light, sometimes suddenly disappearing and leaving streets and houses in total darkness.

"The waters of the Delaware and Schuylkill, now considered the most pure and salubrious in the world, as many long voyages have fully tested, must soon, we fear, experience the deterioration which has reduced the Water of the Thames to the present impure and unhealthy state, for no reservoir will be able to contain the immense fetid drains from such an establishment, and very soon the rivers must be their receptacle, to the destruction of the immense Shoals of Shad, Herring, and other fish with which they abound; the same cause must produce like effects. Salmon, smelts and other fish, formerly caught in vast quantities in the Thames, have nearly all disappeared; the constant digging up of the streets, the circumstance of the gas pipes which at the intersection of each square must come in contact with the water pipes, are difficulties and evils which we would anxiously avoid.

"In conclusion we earnestly solicit that the lighting of our city with oil may be continued.

"And your petitioners, etc., etc."

If the signers of this petition could appear upon the scene to-day and witness the splendid achievements of gas under the management of your great Philadelphia company, I am sure they would be in favor of the "recall," at least in so far as it applied to their petition.

But the opposition to the use of gas should not surprise us. It seems to be a fundamental trait of human nature to oppose, for a time, everything that is new. Coal had the same prejudice to overcome. In the year 1306 the use of coal in the place of dry wood and charcoal by brewers, dyers and other artificers employing great fires was prohibited by proclamation at London. It was held that the products of its combustion, smell and smoke were prejudicial to health and hurtful to vegetation. Its use was made a capital offense, and we are told that a man was actually executed for burning coal within the metropolis. What a boon such a law would be to the gas companies to-day!

It does not take long, however, for human nature to get used to novelty, but remarkable it certainly is, considering the difficulties of communication and the meager resources of a new country, that America was but little behind Europe in the use of gas.

The history of the pioneer gas companies of this country shows that in addition to, and to a considerable extent because

of, the prejudice that existed against the new and supposedly dangerous illuminant, it was a very difficult matter to secure the necessary capital to erect and operate the plants, and it was some time before the industry was established on a commercially sound and profitable basis.

Gas as an illuminant has had several competitors which at the time of their appearance in the field threatened its existence. In the early days of the industry the gas manufactured had an illuminating value of about 15 to 17 candle power. Compared with the light of candles or of the crude whale oil then in use it was considered a wonderful illuminant. This superiority was soon threatened, however, by the introduction of kerosene and improved oil lamps, the general use of which interfered seriously with the rapid increase of the sale of gas.

These conditions would have greatly retarded the growth of the industry had not the problem been solved by Du Motay and Lowe, the former a Frenchman and the latter an American, who independently of each other were carrying on experiments which were to result in the introduction of the so-called water-gas. The investigations of both Du Motay and Lowe were conducted in this country, so that the development of the water gas industry is purely American. The first plant using the Lowe process was erected at Phœnixville, Pa., in 1873. At present, although the exact figures are not available, the census reports indicate that the amount of water gas sold for public use is in the neighborhood of 75 per cent. of the entire quantity of gas sold.

The advent of electricity for lighting purposes did not, as some might suppose, check the progress of gas. On the contrary, as has been the history where improved methods of lighting have developed, both kinds of lighting profited by the increased efficiency; and since the introduction of the incandescent mantle, notwithstanding that the resultant yield of illumination per cubic foot consumed was practically quadrupled, the reduction of gas output did not follow; but, on the contrary, vastly increased. The development of high-pressure incandescent lighting systems, such as are in vogue in the leading European cities, is another movement which bids fair to keep the gas industry to the fore.

PRODUCTION AND PRICES.

The trend of prices for gas has been steadily downward from the beginning. In New York City, for instance, the price in 1826 was $10.00 per thousand cu. ft.; in 1846, $6.00; in 1866, $3.50; in 1886, $1.25; in 1897, $1.20; in 1898, $1.15; in 1899, $1.10; in 1900, $1.05; in 1901, $1.00; in 1906, 80c., the present rate. These reductions have been made possible by various economies in production, and particularly by the more extended utilization of by-products and by promoting the use of gas for domestic and industrial purposes.

Neither gas nor electric light has been a factor in the increased cost of living of which we hear so much. The Massachusetts Commission on Cost of Living reported that the average price for gas in that State in 1890 was $1.46 per thousand cu. ft., and in 1909 91.4c., a decrease of 36.4 per cent. in the period. The Commission also reported an increase in the prices of twelve staple commodities from 1897 to 1910 of 51.7 per cent. During the same period wages also underwent a marked increase. If the experience of Massachusetts may be taken as fairly representative of the country at large, it shows that in a period of steadily advancing prices, both for commodities and for labor, the public has had the advantage of a steadily diminishing price of gas for all purposes.

The output of gas has been continually on the increase, notwithstanding the competition from electricity. From the subjoined table it appears that in 1898 the companies reporting showed total sales of 18,431,200,000 cu. ft., for which $21,502,325 was received, an average price of about $1.17 per thousand. Ten years later, 1908, the companies reporting showed total sales of 156,909,310,000 cu. ft., for which $133,571,122 was received, an average price of 85c. per thousand.

The growth in gas output as compared with the growth in population shows that the gas sales in large cities grow almost twice as fast as the population. For instance, in four great boroughs of New York City the 1890 census and 1910 census compared show an increase in population of 90.6 per cent. in the 20 years, while the increase in gas sales in the 17 years from 1893 to 1910 was 164.6 per cent., or, relatively, per year about 5 per cent. for population and 9.67 per cent. for gas.

GAS SALES.*

U. S. SALES IN CUBIC FEET—AMOUNT AND PRICE PER CUBIC FEET.

	M Cubic Feet.	Total M Cubic Feet.	Average price per M Cu. Ft.	Amount.	Total Amount.
433 Companies Reporting in 1898:					
Sold for Illuminating	15,955,149		$1.188	$18,955,149	
Sold for Fuel	2,476,051		1.029	2,549,181	
		18,431,200			$21,502,325
552 Companies Reporting in 1908 (Oil and Water Gas):					
Sold for Illuminating	76,804,546		.92	70,294,158	
Sold for Fuel	26,542,951	103,347,497	.98	26,049,063	96,343,221
506 Companies Reporting in 1908 (Coal Gas):					
Sold for Illuminating	32,485,571		.73	22,599,930	
Sold for Fuel	21,076,242	53,561,813	.65	13,627,971	37,227,901
Total Coal and Water Gas Sold		156,909,310			$133,571,122

COMPARATIVE STATISTICS—FOUR BOROUGHS OF NEW YORK CITY.

	Population:		
1890:	Manhattan	1,441,216	
	Bronx	88,908	
	Brooklyn	838,547	
	Queens	87,050	
			2,455,721
1910:	Manhattan	2,331,542	
	Bronx	430,980	
	Brooklyn	1,634,351	
	Queens	284,041	4,680,914
	Gain in 20 years—4 Boroughs		2,225,193 = 90.6%

* Compiled from report of Dept. of the Interior, U. S. Geological Survey—1902 and 1908—E. W. Parker.

Gas Output:	M cu. ft.	M cu. ft.
1893: Manhattan & Bronx	11,343,000	
Brooklyn & Queens	3,439,000	14,792,000
1910: Manhattan & Bronx	27,217,105	
Brooklyn & Queens	11,900,000	39,117,105
Gain in 17 years		24,335,105 = 164.6%

Population in four boroughs—4,680,914.
Sales in four boroughs—39,117,105,000 cu. ft.
8,350 cu. ft. per capita per annum.

GAS SECURITIES.

Gas has unquestionably for many years been a staple commodity and its growing field of usefulness in industrial work as well as for cooking, heating and other domestic purposes, has given gas securities a standing and stability hardly approached by any other class of investment. As has been shown, its ratio in increased output far exceeds the ratio of growth of population; for instance, the United States Census shows an increase in the decade from 1900 to 1910 of about 21 per cent. In about one-third of this time, that is, from 1905 to 1908 the sales of gas increased from 117,866,000,000 cubic feet to 156,909,000,000 cubic feet, an increase of 39,043,000,000 cubic feet, or 33 per cent. in three years. This would indicate an approximate increase of 100 per cent. in the decade or five times the ratio of increase given for the population, from which we may conclude that gas securities are destined to maintain their high place as desirable investments.

It is claimed that no other class of bonds shows such a small percentage of defaults as gas securities. Quoting from a recent article in one of the financial journals we have the following:

"Gas bonds have a first class record for safety; they are usually secured by a mortgage on all the property rights and franchises of the company issuing it.

"The condition and value of the property are passed upon by competent gas and mechanical engineers before the bonds are issued.

"The bonds are issued only with the approval of a trust company, which is the trustee, after the trust companies have decided that the bonds may be issued in accordance with the terms of the mortgage and trust

deed. A gas company operates under the franchise or license of a city and usually only one company serves one community. It is a 'necessity' and the residents of the community use gas for cooking and lighting with practically the same certainty that they pay taxes or use the utilities furnished by the municipality itself. The business is operated on a broad foundation, relying on a small profit from many customers rather than a large profit from a few."

A study of the gross and net earnings of lighting companies shows that the effect of periods of commercial depression such as were experienced in 1907 and 1908 is slight as compared with the effect upon the earnings of general industrials. The variation between the two is very marked for such periods, the earnings of lighting companies showing a material gain, while those of general industrials show a decided falling off.

A tabulation covering three years for sixty-one prominent cities in the United States, all of which have well established sources of electrical supply, shows an increase in gas consumption from 1899 to 1902 of 31 per cent. In its widening field for industrial purposes, two powerful factors work for its development, the first of which is the fact that it requires no space for storage on the users' premises. Secondly, it is smokeless and eliminates the troublesome factors encountered in almost all other fuels—the handling of the fuel itself, incidental refuse, ashes, and the like.

In view, therefore, of the position of the gas industry, its continued growth and the variety of purposes to which its services may be put, it is fair to predict that, properly operated and with constant provision for invention and improvement, the business will steadily increase.

SOME AGENCIES FOR PROMOTING THE SALE OF GAS.

No discussion of the subject that has been assigned me in this series would be complete without a reference to the work of the National Commercial Gas Association which forms a most important connecting link between the producer of gas and the user.

It is conceded that a material factor in reducing the cost of gas production is increasing the output.

It is of course of vital importance that the product of the plant shall be of the required quality and that its manufacture

and distribution shall be at the minimum cost consistent with quality requirements. This is certainly worthy of the best thought and effort of the technical man, and this work is likely to make such a demand upon his time as to preclude the possibility of his devoting any considerable attention to the commercial problems connected with the industry.

Salesmanship has become a science, and interchange of ideas and the discussion of ways and means for selling the engineers' product, make the importance of Commercial Gas Associations loom very large in the gas world of to-day, as it is mainly through the development and extension of this arm of the industry that the problem of enlarging the field of usefulness of gas must be solved.

It is with us as with other industries, if we are to have the highest efficiency, it must be through specialization. I believe the money of the gas company is well spent when it develops specialists in the selling line, and this brings to mind the fact that a close observation should be kept over the office man to see that those who deal with the public are sufficiently well informed and have the capacity to supplement thoroughly the salesman's work and to deal with the public in a satisfactory manner.

The commercial gas men have inaugurated aggressive selling campaigns, have instituted schools of salesmanship and have brought together the manufacturer, seller and user of gas appliances at their conventions, an important feature of which is the exhibition and demonstration of the latest and best gas-using devices. I am informed that a Commercial Gas Association has been formed in London similar to that in this country.

I am also a firm believer in the value to lighting companies of newspaper publicity; that is, going direct to the public through the advertising columns of the daily papers, telling in a plain, straightforward way of our product and our service, explaining the things which to the trained gas-man may seem rather elementary but which to the average man are more or less of a mystery. I know of nothing that is more promotive of good relations between the gas company and the public than a frank declaration of the principles and policies of the company, as a public service corporation, made without reservation and thoroughly lived up to. Following the establishment in this way of

a broad foundation of confidence, the company may advertise special appliances or particular features of its service, of the more strictly "business-getting" sort, with the certainty that the returns will amply justify the expenditure.

But even to-day a man ushered into the lighting world faces a field filled with skeptics. In the minds of many there is an inherent feeling of bias against the lighting man, primarily perhaps by reason of the fact that the average individual has no conception of the commodity we sell, its manufacture, the immensity of the time, money, energy and skill required to build up a gas lighting business; and this feeling of distrust is augmented by the fact that the commodity is of so intangible a nature that the buyer of it has no visual knowledge of its coming into his possession as a commodity; to the average man, *selling gas* is a thing apart from *selling light*. The commercial proposition of selling our commodity is further handicapped in the operation of selling as compared with other products which may be shown by the seller. It lacks attractiveness in display, in fact has none itself, cannot be basketed and bundled up and carried away by the user who has chosen his purchase for its attractive appearance, has seen it measured by the yard or bushel, or weighed by the pound and taken in the hand and carried to the house. The gas-man has also inherited a deep seated antipathy of the user of his product by reason of the uncommercial methods of many of his predecessors in the business. Dealing as we do with all classes, all nationalities, all grades of people, and with those who to a great extent commenced doing business with us with this inherited prejudice, we are at once put upon the defensive. In dealing with the commercial proposition we must make a large portion of our work the uprooting of this prejudice, and this does not demand so much of our engineers and gas makers as it does of our commercial department men, those who meet the public and who are large factors in our service. And this word *service* should show up large before the employee of any public utility corporation. The shortcomings of a supply as to pressure, candle-power efficiency and other essentials, are apt to be the matter of a moment and when remedied in a gracious manner leave no rankling; but the shortcomings which are evident in poor service, brought about by inattention, neglect, or slipshod methods, are not so easily effaced

from the consumer's mind; so I say that this word *service* should be writ large in the mind of every worker for a public utility corporation. Some of our forbears did not appreciate this end of the business as vital to the commercial success of our industry, but we are getting away from old-fashioned methods and we feel that we have made great strides in this direction in the last few years.

When one reflects upon the truism that "one man on the block makes public opinion" and that there is large probability of there being at least one unreasonable individual living within the area of a city block, it is not strange, in view of the fact that the satisfied gas consumer does not go to the trouble of announcing his satisfaction from the housetop, that is, not to the extent of disturbing his neighbors or keeping them awake with his joyous ebullitions, that the gas man is on the defensive a very considerable part of the business day. And this is in part because the gas man has allowed an air of mystery to surround his business. He has not given enough time and attention to educational work amongst his patrons—has not tried to explain the workings of that mysterious black tin box in the cellar, of which the average consumer stands in dread and to whose ear the little clicking noise of its mechanism is so ominous. Happily we are to-day on the road to enlightening our customers by giving to our employees a knowledge of these common things of the business, of which up to a comparatively recent time they were wofully ignorant.

IMPORTANCE OF LIGHT TO THE GROWTH OF CITIES.

As a factor in the growth of cities it is generally conceded that the lighting company is a positive force for the general good. The importance of its work of providing the public with more and better light is appreciated by all who are connected with the development of municipalities and particularly of suburban districts. The value of light to a municipality from the purely commercial point of view is becoming more and more recognized, as is evidenced by the agitation among merchants the country over for additional street and store illumination. These tradesmen know well the value of illumination, both in the matter of window display and in the general publicity it attracts to the lighted district and to the city as a whole.

a broad foundation of confidence, the company may advertise special appliances or particular features of its service, of the more strictly "business-getting" sort, with the certainty that the returns will amply justify the expenditure.

But even to-day a man ushered into the lighting world faces a field filled with skeptics. In the minds of many there is an inherent feeling of bias against the lighting man, primarily perhaps by reason of the fact that the average individual has no conception of the commodity we sell, its manufacture, the immensity of the time, money, energy and skill required to build up a gas lighting business; and this feeling of distrust is augmented by the fact that the commodity is of so intangible a nature that the buyer of it has no visual knowledge of its coming into his possession as a commodity; to the average man, *selling gas* is a thing apart from *selling light*. The commercial proposition of selling our commodity is further handicapped in the operation of selling as compared with other products which may be shown by the seller. It lacks attractiveness in display, in fact has none itself, cannot be basketed and bundled up and carried away by the user who has chosen his purchase for its attractive appearance, has seen it measured by the yard or bushel, or weighed by the pound and taken in the hand and carried to the house. The gas-man has also inherited a deep seated antipathy of the user of his product by reason of the uncommercial methods of many of his predecessors in the business. Dealing as we do with all classes, all nationalities, all grades of people, and with those who to a great extent commenced doing business with us with this inherited prejudice, we are at once put upon the defensive. In dealing with the commercial proposition we must make a large portion of our work the uprooting of this prejudice, and this does not demand so much of our engineers and gas makers as it does of our commercial department men, those who meet the public and who are large factors in our service. And this word *service* should show up large before the employee of any public utility corporation. The shortcomings of a supply as to pressure, candle-power efficiency and other essentials, are apt to be the matter of a moment and when remedied in a gracious manner leave no rankling; but the shortcomings which are evident in poor service, brought about by inattention, neglect, or slipshod methods, are not so easily effaced

from the consumer's mind; so I say that this word *service* should be writ large in the mind of every worker for a public utility corporation. Some of our forbears did not appreciate this end of the business as vital to the commercial success of our industry, but we are getting away from old-fashioned methods and we feel that we have made great strides in this direction in the last few years.

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Light is the world's best policeman, for crime instinctively seeks the shadows and the dark corners. I believe that many of our American cities could find no better way of co-operating with the efficient police bodies they have than by thoroughly illuminating the communities to the very limit of municipal control.

In King's Treatise we are given this interesting information concerning the early days of gas lighting:

> "The police officers from Worship Street and other places gave evidence of the great utility of gas lighting in preventing robberies, and they also mentioned an instance where perpetration of this crime had been apprehended by its aid. Also that three-fifths of the street oil lamps were extinguished before midnight, and that the thieves would borrow ladders from lamp lighters for the purpose of committing robberies."

This was brought out in connection with an application made in London, in 1816, by the Chartered Gas-Light & Coke Company for an increase in capital.

THE MODERN GAS COMPANY IN ITS RELATION TO THE PUBLIC AND THE MUNICIPALITY.

As a necessity; as a convenience; as a promoter of trade; and as a source of good or ill-will as between the company and the community—the last named largely in proportion to the degree with which the company's affairs are conducted with business sagacity and common sense. It is a public service corporation. Its rights and the rights of the consumer must be safeguarded if both are to realize beneficial results. It is not a one-sided proposition; one falls unless the other is supported. They are inter-related; they should be friends, not enemies. It is a mischievous interpretation of their relations that groups all the wrongs on one side and all the rights on the other.

To repeat before such a representative body as this all the arguments for the company and for the consumer is not my purpose, nor is it necessary at such a time. It is sufficient to say that the relation of the company to the municipality should be characterized by integrity and efficiency of management and fair and impartial treatment of all who do business with it. In turn, when the public is fairly and efficiently served, that is, with the best service at the lowest rates compatible with a just

estimate of their respective relations, the municipality should support and encourage the company. As I have said upon another occasion, the public is less concerned with the precise rate it pays than it is with having thoroughly efficient service. If the company is honestly conducted and its affairs are given that degree of publicity which is proper and is the public's due, it does not begrudge to the company adequate returns, nor will it yield to the screamings of the demagogue and the self-seeker when he misrepresents the facts or encourages unjust attacks. On their side the companies must keep out of politics, and the mystery of management must become less of an obsession with those who have important undertakings of this character entrusted to their hands.

Of course all this presupposes a full recognition of the rights of employees. No company will have permanent success, or deserve to have it, unless those whose labor has so vitally to do with the enterprise are regarded as an integral part of it. Adequate wages, reasonable hours, generous treatment all along the line, with a system of management that encourages to the highest possible degree the spirit of the individual worker, are all their due and are recognized by the enlightened corporation.

If there is one thing more than another that is a menace to industrial progress, I believe it is the untenable position assumed by some extremists who would limit the return allowed to such corporations as those which are of the public utility class to a rate so low that it either barely equals the legal rate of interest, or, taking into account the varying factors that must be considered in the case of each company, a rate that is practically but a fraction above confiscation. To induce original investment and development, to insure progress after establishment, to safeguard both the company and the community, a return not merely theoretically but actually fair and liberal must be permitted if the normal laws of trade are still in effect, and we believe that they are.

It should be remembered that when franchises were granted to public utility companies they were granted with the idea that a service absolutely essential to the growth of the community was to be provided, and it must also be remembered that in many cases those who obtained these privileges or franchises faced a serious risk in making their investment, that there was no as-

surance that an adequate return would be forthcoming for the money and energy expended in the building up of the service.

A factor which the unthinking man should have brought to his notice when the supposed enormous profits accruing to lighting companies are discussed, is the ratio between investment and gross income. Investigations show that the annual gas sales of many of the companies do not exceed $15 for each $100 of investment. It must not be inferred from this that these companies make $15 per year on every $100 investment, but that their actual sales each year amount to but about one-seventh of the money invested. This would indicate an investment of $7.00 for each 1000 feet of annual sales at $1.00 per M approximately. In other lines of business it is expected to turn over the capital once, twice or three times a year, but here is a business in which millions are invested in which the capital is turned over only once in about seven years.

It has come to be well-nigh axiomatic in the gas industry that each company must be considered on its merits, that hardship and injustice result when one company is expected to meet all the requirements of the business under the same restrictions as every other. Engineering difficulties, extent of territory, character of population, maximum demand and a number of other considerations must in each instance be given their fair and proportionate bearing upon the entire problem.

But we cannot expect all of the desirable factors to which I have alluded to be fully developed at once; substantial and permanent progress in any industry, in any line of human endeavor, is usually of slow growth. But we can work toward them with the certainty that the material returns will be gratifying, and that we shall be contributing, if only in a slight degree, to the establishment of efficiency and equity and justice in our commercial transactions.

FRANCHISES.

An official of one of the largest and most active of our American companies dealing in and having to do with the management of public utilities, Mr. Arthur S. Huey, quite recently gave utterance to some suggestions on the subject of franchises that will bear frequent repetition, and I am presuming upon his

courtesy in embodying them in this paper. They were contributed to a well-known publication a few months ago and admirably voice the sentiments of progressive managers. Said he:

"The principal obligations of both parties to a franchise should be—

On the part of the Utility Company:

1st. Rendering of good, adequate, and continuous service.

2nd. Fair and reasonable rate schedules.

3rd. No discrimination among consumers of the same class, or between classes of customers for like service.

4th. Extension of service into all populated sections of the municipality and suburbs.

5th. Earnest endeavor to market the greatest possible volume of service.

6th. Adoption of approved inventions and developments in machinery and apparatus.

7th. Sound financial management.

8th. A high standard of physical maintenance.

9th. Public spirited attitude in all matters concerning the general welfare and advancement of the community.

10th. Broad and liberal business administration.

11th. Keeping faith with the people in all agreements, promises and announcements.

12th. Strict obedience to law and no participation in politics.

On the part of the public:

1st. The same degree of confidence, encouragement and respect that one business man accords to another, that any citizen expects from his neighbor.

2nd. Willingness to permit a fair profit on the capital, energy, ability and risks embodied in the undertaking, to permit a profit greater than mere interest which could be obtained without effort or hazard.

3rd. Disregard of attacks by popularity seeking agitators.

4th. Willingness to recognize and reward improvements in service.

5th. Recognition of the fact that the operation of utilities differs fundamentally from merchandizing or manufacturing.

6th. Reasonableness in demanding large capital outlay for improvements not strictly necessary to the rendering of adequate service, such as placing wires underground in cities of small or medium size.

7th. To make prompt payment of bills, because the company cannot render the service demanded if its only source of income is retarded.

8th. Protection against direct competition. All authorities agree that public utilities can be conducted with greatest benefit to the public as controlled monopolies.

9th. Careful consideration of legislation, municipal, state and national, which would hamper and curtail the development of utilities.

10th. Recognition of the fact, that, starting from a given base line, which varies in different localities, reductions in rates can be secured without financial loss only by increasing the volume of service sold.

11th. Recognition of the fact that no utility company can well serve a

municipality if it is not in prosperous condition, and able to secure the investment of new capital on favorable terms.

12th. Treatment of all questions affecting public utilities in a fair minded way, looking upon them as business questions without regard to political considerations."

MUNICIPAL AND PRIVATE OWNERSHIP.

Public utilities in the United States, in their establishment, development, and successful operation, have resulted almost wholly from private initiative and private capital.

There are probably not more than twenty-five municipally owned and operated gas plants in this country.

Under a system of municipally controlled utilities it may be expected that—

"Operating costs will be, as they have been, materially increased by the demand for preferment and for employment of men whose services are not actually needed. The salaries being fixed by a council dependent upon public suffrage, makes it possible that there be no limit to the number of positions to be created and no control over the remuneration established for them.

"The rule of municipally owned plants is to cut rates to a point below cost of production and make no allowance for depreciation and often no interest is charged off against the investment.

"Expensive extensions are made to favored firms and when the time comes for renewals and repairs, the taxpayer will be asked to appropriate funds from the treasury or stand sponsor for a bond issue.

"Economy of operation and advantageous selling are the great factors that must determine the success of any lighting enterprise."

The operations of municipally controlled lighting plants are largely confined to street and municipal building lighting and do not as a rule furnish the citizens as individuals. Consequently they cannot be compared with the operations of a company supplying individual dwellers in a municipality; but where we have an opportunity of making comparisons of somewhat similar lines of operation, the results are certainly not unfavorable to the private companies.

The report of a committee of the National Civic Federation, that investigated the subject, calls attention to—

"the danger here in the United States of turning over these public utilities to the present government of some of our cities. Some, we know, are well governed, and the situation on the whole seems to be improving, but they are not up to the government of British cities. We found in England and

Scotland a high type of municipal government, which is the result of many years of struggle and improvement. Business men seem to take a pride in serving as city councillors or aldermen, and the government of such cities as Glasgow, Manchester, Birmingham and others includes many of the best citizens of the city. These conditions are distinctly favorable to municipal operation. . . .

"However, there seems to be an idea with many people that the mere taking by the city of all its public utilities for municipal operation will at once result in ideal municipal government through the very necessity of putting honest and competent citizens in charge. While an increase in the number and importance of municipal functions may have a tendency to induce men of a higher type to become public officials, we do not believe that this, of itself, will accomplish municipal reforms. We are unable to recommend municipal ownership as a political panacea."

COMPETITION VS. MONOPOLISTIC CONTROL OF PUBLIC UTILITIES.

Quoting from the Wisconsin Railroad Commission:

"Duplication of such plants is a waste of capital, whenever the services can be adequately furnished by one plant only. It necessarily means that interest and maintenance must be earned on a much greater, if not twice as great, an investment, and that the actual cost of operation is likely to be relatively higher. Competition in this service therefore usually means a bitter struggle and low rates, until one of the contestants is forced out of the field, when rates are raised to the old level if not above it, or to a combination or understanding of some sort between them which also ultimately results in higher rates. In this way it often happens that the means which were thought to be the preventive of onerous conditions become the very agents through which such conditions are imposed. In fact, active and continuous competition between public utility corporations furnishing the same service to the same locality seems to be out of the question. This has been shown by experience. Such competition is also contrary to the very nature of things. Two distinct and separate corporations are not likely to remain separate very long after it becomes clear that the services rendered by both can be more cheaply and more effectively furnished by only one of them."

The Public Service Act of New York was enacted with the expressed intent that no more capital be invested than is required efficiently to supply the desired service, and it therefore not only restrains the issuance of stocks and bonds, but for the same reason also restrains the operations of new companies "unless necessary or convenient for the public service." In order to produce the most favorable economic conditions in the operation of utilities, it is intended to prevent the economic waste which is inseparable from needless duplication of capital; and in

justice to existing corporations it is clearly the duty of the Public Service Commission to protect them from destructive competition, which would or might jeopardize the interests which have promoted the existing service by depriving them of a just return upon their invested capital, and prevent them from giving efficient service by so impairing their earnings as to make efficiency impracticable.

REGULATION BY COMMISSION.

If the question of rates is to be determined, in any degree, by a public body, it is a safe proposition to advance that a Public Service Commission, if rightly constituted, would be far better able to pass upon such an important matter than a legislature. With facilities which would be available by a Commission, a more intelligent understanding could be had of conditions which should govern in such matters. The process of finding out by qualified experts through long and exhaustive research is not what would be at the command of a legislative body dealing with a voluminous public business in short sessions. Such a Commission, which has gained the confidence of the public and the lighting company, is better able through the investigation of its experts to cope with this intricate subject than a body which, as a body, has no particular local interest in such a matter as gas rates.

In the larger communities, competitive control of the gas industry has given place largely to monopolistic control, and this tendency received a great impetus in the establishment of State commissions to regulate and supervise various features of the business. In certain lines of business, regulated monopoly appears to be here to stay, and this is especially true of this industry. It is well that this is so, for the industry is certainly one of a class where competitive conditions work not only loss, hardship, and discomfort to the public, but in the weaker companies tend to inefficiency and generally poor service.

But regulation must not mean management, and it will not be construed as in any sense to mean management if commissions are constituted of competent and broadminded officials. On the other hand, there cannot, with justice to the public or to the corporations, be left a twilight zone in which neither appears to have jurisdiction. The light of common sense must be made

to shed its rays upon this whole question, and when that day has fully dawned we shall find the exactions upon the corporations less burdensome and the resistance of the corporations to wise and reasonable requirements eliminated.

This centenary celebration is a milestone in the progress of one of the world's great industries. These hundred years have given to mankind many of the most marvelous of its processes and of its inventions. In a gathering of this character we draw upon the past for its history and its lessons. Knowing by these means of the character of the pioneers in the gas industry, and of many of their successors by more intimate association, I believe these men of the present are in a position to contribute much to the solution of problems that to-day confront the business community; and, furthermore, I believe they are alive to this opportunity for beneficent public service.

In this time of industrial unrest the business interests of the country should play a conspicuous and helpful part. Commercial honor is not a rarity; the ethics of trade are not mere memories of a glorious past in the life of the nation. Such generalizations are but the familiar stock-in-trade of the professional agitator or self-seeking politician. But business—big business and small business in all its manifold branches—owes its strength and its progress and its permanency to that ordered liberty whose fostering care it can in no wise so well assure, and when assured repay, as by willing and complete obedience not only to the law of the land but to those higher laws without an observance of which we shall fall far short of our ideals of the true commercial greatness of a mighty people.

Amorphous Silicon. L. CAMBI. (*Atti R. Accad. dei Lincei*, xx, I, 440.)—The chemically active product obtained by the hydrolysis of black silicon sulphide is regarded as consisting essentially of a variety of amorphous silicon. A sample containing 96 per cent. of silicon had the specific gravity 2.08 as compared with about 2.35 for the amorphous silicon of Vigouroux. When heated in vacuo for 1 hour at 900° C. the bright reddish-yellow product was converted into a denser brown substance, much less chemically active and very similar to Vigouroux's product. The active amorphous silicon always contains small quantities of hydrogen and oxygen, probably combined with silicon.

Zinc Alloys Heated in Vacuo. T. TURNER. (*Inst. of Metals*, Jan., 1912,)—It is found that zinc and other metals are entirely removed from brass and other copper-zinc alloys when they are heated in a vacuum. In the case of brass the separation of the zinc is quantitative, provided the temperature does not exceed 1200° C. and the heating is not too prolonged; by subjecting a sample of "poisoned" brass to this treatment all the zinc, lead, and arsenic and a little of the tin were removed at 1200° C. Zinc volatilizes easily at 375° C. in a vacuum, and is readily volatilized from 60/40 and 70/30 brass at temperatures of 520° C. and 540° C. respectively. When 180 grammes of 70/30 brass were melted in a crucible and allowed to cool in an exhausted desiccator, the percentage of zinc in the alloy was sensibly reduced, although the charge could not have remained liquid for more than 3 minutes. On heating zinc with copper *in vacuo*, though the metals were not in contact, the copper rapidly turned yellow at 380° C., the zinc being still solid. When hard zinc (the residue from galvanizing baths, containing about 5 per cent. of iron) was heated to 500° C. in a vacuum, the zinc was completely volatilized, the iron remaining in the residue. The application of this principle to the refining of crude copper, brass scrap, hard zinc, etc., is suggested.

Ice Drift in Polar Regions. O. A. AKESSON. (*Ark. für Mat. Astron. och. Fysik. Stockholm*, vi, No. 40, 1.)—In polar regions the method generally employed for determining latitude and longitude involves the observation of two altitudes of the sun or other celestial object and the corresponding times. This supposes the observer fixed. If the observer be on a moving ice-field, it is possible so to arrange the observations that the position and velocity and direction of the observer may be calculated. Four observations must be taken of the altitude of the celestial object, and the corresponding times. If the time between the first and second observations and between the third and fourth be six hours, while that between the second and third be several days, the positions are determinable, and from these the velocity and direction of the motion of the ice is easy to compute.

Chicle Gum. J. E. Q. Bosz and N. H. COHEN. (*Arch. Pharm.*, ccl, 52.)—The larger portion of chicle gum, which is obtained in Mexico and Central America from *Achras sapota*, goes to the United States, where it is manufactured into chewing gum. The authors have examined it, as Schereschewski did, and find that α-chiclalban consists of almost pure α-amyrin acetate, β-chiclalban is a mixture of lupeol and α- and β-amyrin combined with caproic, acetic, and cinnamic acids. It appears probable that γ-chiclalban is identical with cerotinone. Chiclafluavil is a mixture of all the constituents of the chicle gum.

ALTERNATING-CURRENT DEVELOPMENT IN AMERICA.[1]

BY

WILLIAM STANLEY,
Great Barrington, Mass.

It is my purpose this evening to attempt to describe the conditions of the electric lighting industry and its engineering status at the time that the alternating-current system was introduced; to give, very briefly, the causes which made it necessary to devise a new system of distribution that would remove the difficulties which had temporarily brought the art to a standstill; and to speak a few words concerning its growth.

The alternating-current system of distribution came into use in 1885. It is to be remembered that long prior to this date Mr. Edison had completed his work upon the incandescent lamp in this country and that it had been introduced into many places for the purpose of lighting large buildings; but only about a dozen plants had been installed to furnish incandescent lighting to the public. The labors of Edison, Swan, Weston, and Maxim had developed the incandescent lamp until it had become fairly reliable as well as fairly efficient.

Prior to 1884 Weston had made large candle-powered lamps that were quite generally used for semi-public lighting, and had further greatly advanced the art by his labors in perfecting the continuous-current generator. Indeed, excepting for increased capacity, he produced at that time machines that were fully equal to those of the present day.

But the advance of the art and the general distribution of electricity for domestic purposes was greatly retarded by the fact that the cost of the conductors necessary to convey the current over any considerable distance was nearly prohibitive. It was the common saying of the day that, if one should attempt to light

[1] Presented at the joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held February 15, 1912.

Fifth Avenue from Fourteenth Street to Fifty-ninth Street, the conductors required would be as large as a man's leg.

Dr. John Hopkinson, of England, and Mr. Edison, at about the same time, and independently, devised the three-wire system, which increased about threefold the area over which economical distribution could be made. But even this increase in the possibilities of distribution was insufficient to meet the demands upon the art.

Engineers understood that the solution for the distribution of electricity over long distances would be found by employing some system operating at high potential; and very strenuous efforts were made towards this end.

In 1883 Mr. Charles F. Brush, the well-known inventor, put upon the market a system in which continuous-current generators of high potential fed storage batteries grouped in series connection. The batteries, in turn, fed, locally, incandescent lamps in houses, hotels, and other buildings. High hopes were held for the success of this plan, but battery difficulties and the dangers incident to the high-potential series system finally caused its downfall.

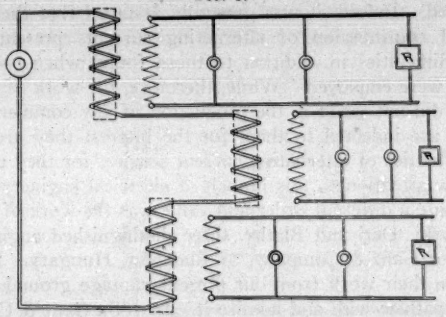
Dr. Weston, Prof. Elihu Thomson, and others attempted, at about this time, to operate a series multiple system in which the potential upon each multiple arrangement of lamps was governed by an automatic device that cut into circuit, compensating resistances whenever the lamps were turned out. This system was introduced in many places, and was especially successful wherever the lighting could be watched and guarded by a local attendant, as in railway stations, department stores, and other semi-public places; but no general solution of the problem was found, and the art hesitated, and its progress was delayed, for the reason that conservative and far-sighted engineers did not recommend its introduction for the general distribution of light and power.

It was while our engineers and inventors were groping about for a solution to the distribution problem that the first suggestions to use alternating currents were made. The Patent Office records of the country show that Jim Billings Fuller, in 1878, applied for and obtained a patent for the use of an alternating-current generator and an induction coil connected to it as a means of distributing electricity; but this disclosure, while it contained

a hint of the true solution to the problem, was so vague and so indeterminate that, so far as I am informed, Fuller never proceeded further than to put his ideas upon paper; and he probably did not understand the governing factors that later proved to be the keynote in the solution of the problem.

In 1884 Messrs. Goulard & Gibbs—the one an Italian engineer, and the other an English promoter—constructed in England an alternating plant for the purpose of distributing electricity by means of alternating currents generated at high potential and induction coils connected in series arrangement with each other (Fig. 1).

FIG. 1.



In this system of distribution a constant value of current is generated (such, for example, as 10 or 50 amperes) and is compelled to flow through the primaries of the induction coils irrespective of the load they may carry upon their secondaries. Such an arrangement means that the electrical potential upon both primary and secondary coils must vary with the variations of their load, and, consequently, if lights are connected to the secondary circuits the candle-powers of these lights will rise and fall as the number in circuit is changed. To obviate this difficulty and to reduce the fluctuations as much as possible, the designers made their coils with straight, open-circuited magnetic cores, and also introduced regulating resistances in parallel with the lamps in circuit. This arrangement, or system, possessed little novelty in the design of its apparatus, and was of no prac-

tical value in the solution of the general problem. It is remarkable that Messrs. Goulard & Gibbs continued to advocate this arrangement after the final solution of multiple-arc connection and constant potential circuits had been disclosed.

At this time (1884) there was, so far as I know, but one firm that was building alternating-current generators, although many attempts to produce successful alternators had been made abroad. Messrs. Siemens Brothers were building alternators to operate arc lamps for light-house purposes. Each machine furnished the electricity for one large arc lamp. The machines of Lontin, Gordon, and other designers had failed to fulfil the hopes of their authors, and had either gone out of service or had been discredited. Indeed, it was generally assumed that the generation and transmission of alternating currents presented very serious difficulties in addition to those found when continuous currents were employed. While, therefore, the work of Goulard & Gibbs did not result in the production of any commercial system, we are indebted to them for the interest they aroused in the possibilities of alternating-current service, for they undoubtedly drew attention to this branch of electrical engineering.

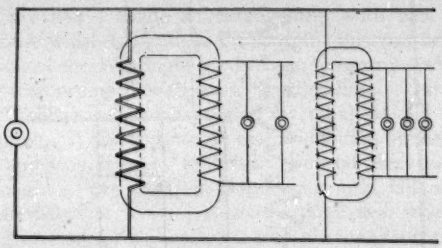
Of quite a different order and value was the work of Messrs. Zipernowski, Deri and Blathy, three distinguished engineers of the firm of Ganz & Company, of Budapest, Hungary. Looking back upon their work from our present vantage ground, we can only sympathize with and admire it. In 1885 Ganz & Company exhibited at a local fair in Hungary a system employing alternators wound for a constant and high potential, induction coils connected in parallel arc by their primary circuits and wound with short and, therefore, low potential secondaries, to which lamps were connected. In fact, they disclosed the alternating-current system as we now use it. Their transformers were made with closed magnetic circuits, were intelligently designed, and were properly constructed. If the work leading up to the Great Barrington plant, of which I shall soon speak, had not been undertaken, and if the plant had not been built, we would still have had the system from Budapest without essential modification. In October, 1885, Zipernowski, Deri & Blathy published a description of their system in the *English Electrical Review*. I am glad to bear testimony to the work of these distinguished men, especially for the reason that Americans have been inclined

to give to the work of Goulard & Gibbs credit which, in my opinion, it is not entitled to, and in which Zipernowski, Deri & Blathy should fairly claim a pioneer's share. (Fig. 2.)

I now am obliged to refer to the work which I carried out in this country and which resulted, in 1885, in the building of the first alternating-current plant at Great Barrington and the introduction to the country, by the Westinghouse Electric Company, of the system there operated. A discussion of one's personal work is somewhat embarrassing, yet I fear I shall have to ask your indulgence while I attempt to describe the influences which led me to pursue the subject.

In 1883 I was tremendously impressed with the Brush storage battery system above referred to. I knew Mr. Brush, and

FIG. 2.



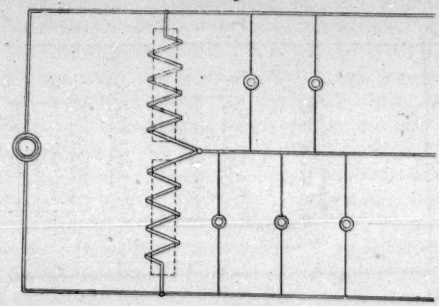
had the highest admiration for his work. Indeed, it was a characteristic of Brush's work that he turned it out in completed and satisfactory form. When, therefore, he announced that his storage battery was perfected and that he had devised a solution to the distribution problem, I was enormously impressed. At that time I was disobeying the laws of chemistry by attempting to produce a battery on a novel but unsuccessful plan. This battery work brought clearly before me the importance of the counter electro-motive force of the battery in maintaining a constant potential upon the service to be supplied. Batteries are clumsy affairs, and in those days they were difficult to handle and troublesome to maintain. The reason that they were employed by Brush was, in reality, to produce this counter, regulating electromotive force—a variable electromotive force that should

adjust itself instantly and accurately to the varying load conditions of the service, and thus maintain a constant potential. I asked myself why such an electromotive force could not be made in some other way—whether it were not possible to obtain it by a rotational device like a motor—and I harassed my brain in searching for some means to attain this end.

On September 18, 1883, I made the following entry in my laboratory notebook (Fig. 3):

A system of multiple series translating devices, each series having an opposing electromotive force shunt in combination with an alternating current dynamo electric machine, etc., whereby the potential between the supply mains is maintained at constant value.

FIG. 3.



I foresaw at that time, dimly, to be sure, but still with sufficient accuracy to realize something of its value, that alternating currents could be used to produce an electromotive force upon the circuit to be regulated, in place of the battery electromotive forces suggested by Brush and the resistance electromotive forces of Weston and Thomson. I do not mean to intimate that at that time I had complete knowledge of the invention—that came later—but that it was the starting point from which I worked until, in 1885, the completed system was developed.

It is difficult for engineers of the present day to appreciate the conditions of that time. Please remember that there were but few books on electrical engineering, no formulæ, except those hidden away in scientific papers, no nomenclature, and there was

hardly any information about alternating-current phenomena available. All of the alternating-current machinery devised prior to this date, with the exception of the Siemens alternator, failed for one reason or another, and there was a popular opinion that there was nothing of value in the alternating-current field. It therefore took definite self-conviction to believe that the solution of the distribution of energy by electricity lay in this despised and rejected line of work. At this time the laws of the magnetic circuit were not generally understood or accurately defined, and it was difficult to find an engineer who had a clear, clean, definite, and easily applicable conception of the subject, so when I began studying induction coils the phenomena that appeared were strikingly novel, and interesting, and to me, at least, it was only possible to have a physical conception of them, not a quantitative estimate of their value.

Early in 1884 I made an arrangement with Mr. George Westinghouse which took me to Pittsburgh—this was before the organization of the Westinghouse Electric Company—where for a while I was swamped with work in other lines. During this busy year (1884) I was carrying in my mind the old problem of distribution. It had become my major ambition by this time—my secret ambition, if I may confess it. Several times during the year I thought to get at it, but I could not until fall; and as I had no alternator at hand, I wasted a good deal of effort in attempting to transform continuous into alternate currents by a special form of induction coil having two opposite wound primary circuits, one secondary, and a commutating device. It worked, some, but oh how it sparked! In experimenting with this device, I realized the importance of the closed magnetic circuit in reducing the intake or magnetizing current, and convinced myself then that if the commutating difficulties were disposed of the system would solve the problem. I don't know that I would go quite so far now.

By the spring of 1885 my health gave out, and there seemed to be a grave question as to my ability to withstand Pittsburgh and its work. My doctor began to advise me to go to the country. I was rather discouraged, for the surroundings were uncongenial, the work hard, and the results meagre.

One day when the experimental work was troubling me Mr. Westinghouse told me that he could get an option on the work of

Goulard & Gibbs, and suggested that he send for their alternating (Siemens) machine and their induction coils. I told Mr. Westinghouse that I did not think the system commercially useful, but that I appreciated its coming—particularly the alternator—and this led me to tell him that if the induction coils were wound for parallel instead of series connections, as used by Goulard & Gibbs, the distribution problem would be solved, as each coil would then operate independently of the others in circuit and would be self-regulating, both as to electromotive force and current transformed.

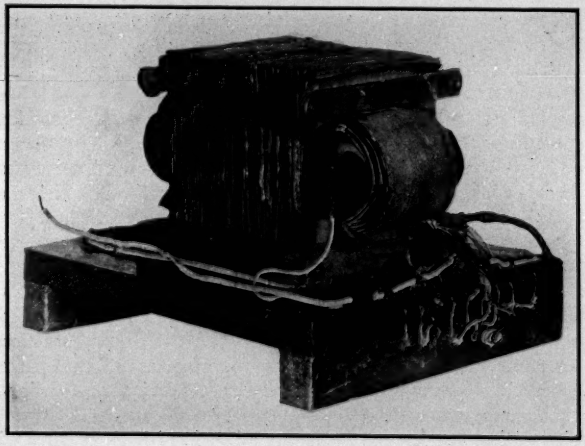
The study and effort I had given to the development of my commutator-transformer cleared and defined my notions. I realized that if we could make a transformer that would regulate the energy transformed by slight variations of its induced counter electromotive force in the same manner that a shunt-wound motor regulated for energy transferred by variation of its rotational counter electromotive force, the problem would be beautifully solved. I saw this analogy faintly at first, but soon with strong and clear conviction. I was very much excited by it. It seemed too simple and too easy to be true. I was almost afraid to believe or speak of it, for I had experienced a good many disappointments and was in a nervous and overworked condition; but as my convictions grew and strengthened I gained courage. Then I clearly saw that the solution was found. I told Mrs. Stanley, and, although she did not understand a word about it, she saw it too.

At this time Franklin Leonard Pope was a conspicuous and important factor in electrical engineering matters. He was also adviser to the Westinghouse interests. I pointed out to Mr. Pope the similarity of the parallel connected transformer to the shunt-wound parallel connected motor. I waxed eloquent over the automatic regulation of the system of parallel connection, and tried my best to picture the phenomena clearly to him. But Pope's conviction came slowly—more slowly than my patience could stand. He pointed out that if high potential primary circuits of 500 volts or more were used to distribute electricity throughout a community, there was a grave fire and life danger, and he held back and did not at first approve of the plan.

For this reason, I suppose, Mr. Westinghouse hesitated to furnish the money necessary for me to experimentally prove my

views, and for a moment I was at a loss to know what to do. I had a little capital, and finally I made a trade with Mr. Westinghouse and sold him half of my holdings, realizing several thousand dollars, and agreed to use the funds so obtained in experimental work for the company's benefit. This arrangement now seems a trifle one-sided, as I did not benefit by it excepting as a stockholder in the company; but I suppose that Mr. Westinghouse was doubtful of my success, and therefore did not feel justified in putting up the money. For my part, I feel that I

FIG. 4.



made the best bargain of my life, for, with the enthusiastic approval of the one who never hesitated at taking a chance—the one whose courage never failed—we packed our belongings, shook the dirt of dreadful Pittsburgh from us, and hastened to the green fields of Berkshire, to build a laboratory and succeed or perish in our work.

Before leaving Pittsburgh I designed several induction coils, or transformers, as we now call them, for parallel connection. One is here shown. (Fig. 4.) It was designed in the early sum-

mer of 1885 and wound for 500 volts primary and 100 volts secondary electromotive force. It is the original transformer now in the library of the Electrical Engineering Society, and is the prototype of all transformers since made. Several other coils were constructed for experimental information—one with a variable air gap in the magnetic circuit, and several with iron wire cores.

During the midsummer months I was too indisposed to work, but when the cool September nights came on my health came back, and I started in to equip my laboratory.

At the north end of the village of Great Barrington was an old, deserted rubber mill. This I leased for a trifling sum, and erected in it a 25-horsepower boiler and engine that I purchased for the purpose. I have frequently met, in a long and stormy life, serious and obstinate difficulties, but I have never encountered any mechanism, of any kind whatsoever, that possessed so profound a genius for going wrong as this engine. My engineer once offered to bet the engineer of the woollen company ten dollars that my engine could pump all the steam and water from their battery of boilers in twenty minutes, and I believe that if he could have kept her going for that time he would have won. After about a month's work we synchronized the power plant—got the pump injector, boiler and engine to agree to work on the same day.

After what seemed another interminable delay we at last installed the Siemens alternator that Mr. Westinghouse imported from London. In the meantime I had started the construction of a number of transformers in the laboratory, and engaged a young man to canvass the town of Great Barrington for light customers.

The Siemens alternator was wound to furnish 12 amperes of current with a maximum of 500 volts. Having a very high armature inductance, it was very sensitive to load variations. Starting out from the old rubber factory in which the laboratory and plant was installed, two No. 6 white underwriter wires were stretched down the main street of the village and fastened to insulators nailed to the big elms bordering the sidewalks. A pair of No. 10 wires were connected from the centre of distribution of the system and brought back on separate insulators to the laboratory in order that we might determine the exact drop of the line under variations of load. Finally, after the wiring was com-

pleted, half a dozen transformers were installed in our customers' cellars. They were placed in wooden, skeleton boxes covered with mosquito netting and kept under lock and key (Fig. 5).

We built in all at the Great Barrington laboratory twenty-six transformers, ten of which were sent to Pittsburgh to be used

FIG. 5.

in a demonstration plant between the Union Switch and Signal Company's factory and East Liberty. This plant was operated a year after the Great Barrington plant had demonstrated the operativeness of the system. We installed in the town plant a Barrington two 50-light and four 25-light transformers, the remainder being used in the laboratory for experimental work. Of the twenty-six transformers built, one short-circuited under

test. The transformers in the village lit thirteen stores, two hotels, two doctors' offices, one barber shop, and the telephone and post offices. The lamps were of 150-, 50-, and 16-candle-power sizes. The length of the line from the laboratory to the centre of the town was about 4,000 feet.

At this time I called my induction coils "converters," coining this name for them. It was adopted generally. I really did not quite like the name, and one day I asked my friend Senator Hosmer, the local scholar, to come to supper, and after explaining to him the action of my converters asked him to improve the name. He suggested that "converter" implied a conversion of one kind of thing to another kind of thing, but that "transformer" was more applicable to the device. I, however, hung on to "converter" until later, in England, I believe, they adopted the change that Hosmer had suggested.

We first devised and tried out at the Great Barrington laboratory the step-up and step-down transformer system now so generally used for power transmission, the generating electromotive force being transformed from 500 to 3,000 volts and from 3,000 back to 500 volts, and then sent over the line downtown. Lamps connected in series across these voltages gave voltmeter evidence that these transformations were really performed. This, so far as I know, was the first high-potential, alternate-current transmission line ever attempted.

I find from my old record books that the town plant was not put into regular service until March 6, 1886, but long before this time the system was tried out and had vindicated itself. At last the town was lighted, and we had ocular evidence of our success. We made a gala night of it. The streets and stores were crowded with people, the big 150-candle-power lamps were running at about double their candle-power, and my townsmen, though very skeptical as to the dangers to be encountered when going near the lights, rejoiced with me.

This plant continued to operate successfully, with the exception of one small fire, until an attendant, in the summer of 1886, dropped a screw-driver into the alternator and ruined it.

Long before this, however, I became convinced that the Siemens alternator did not possess the characteristics necessary for the best operation of the system. Between November 5 and 15, 1885, I designed and completed the drawings of a new alternator

—the radial pole type of machine now so well known—and sent them to Pittsburgh. This machine proved a really remarkable designing success. It was calculated to deliver 500 volts with a drop of 2 per cent. between full and no load when running at a thousand revolutions and with 10 amperes of excitation current. It actually gave 490 volts under these conditions, while its inherent regulation was very close to the amount predicted. Furthermore, it was decently cool.

I presume the design of such a machine seems a very simple matter, but in those first days it was no trifling experiment, for many attempts to build alternators having iron cores with strong fields had been unsuccessful. I took the position that a constant potential alternator should have these characteristics, and that a machine could be devised that would give them. (Fig. 6.)

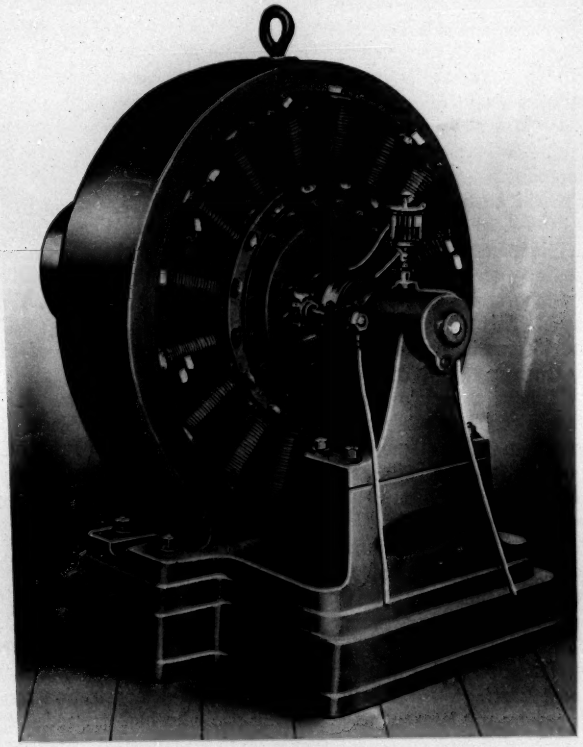
On April 6, 1886, Messrs. George and H. H. Westinghouse, William Lee Church, Guido Pantalioni, H. H. Jackson, Franklin L. Pope, and Walter C. Kerr came to Great Barrington to visit my laboratory, where they saw the system working for the first time. This visit determined Mr. Westinghouse to actively enter the alternating-current field, as the novelty and scope of the system surprised him greatly.

I have a very personal affection for a transformer. It is such a complete and simple solution for a difficult problem. It so puts to shame all mechanical attempts at regulation. It handles with such ease, certainty, and economy vast loads of energy that are instantly given to or taken from it. It is so reliable, strong, and certain. In this mingled steel and copper, extraordinary forces are so nicely balanced as to be almost unsuspected. This equilibrium is remarkable. It is like putting on the pans of a delicate chemist's balance 10-pound weights so exactly timed in their application that never a tremor stirs the needle from its mark.

The success that attended the demonstration of the system at Great Barrington was followed by a second demonstration conducted by the late Oliver Shallenberger, who had succeeded to my place as engineer for the Westinghouse interests in Pittsburgh. Mr. Shallenberger erected the alternator shown in Fig. 6 above mentioned at the Union Switch and Signal Company's works in Pittsburgh, and ran a line from Pittsburgh to East Liberty, distant about three miles. At the far end of the line he also erected the transformers which I had built for that

purpose at the Great Barrington laboratory, and he made careful measurements of the drop of potential and efficiency of distribution. The results of these tests were very encouraging. Mr.

FIG. 6.



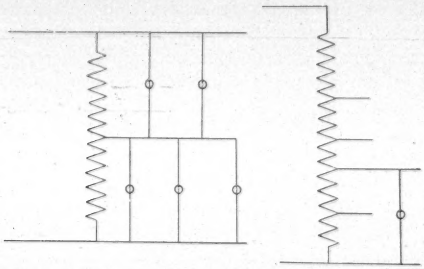
Shallenberger next increased the potential of the alternator and rewound the transformers to operate at 1,000 volts, and again tested out the system.

Convinced that a general solution for the distribution problem

had been found, Mr. Westinghouse at once undertook to place the system upon the market, and in the winter of 1886–87 erected at the Buffalo Electric Company's station the first commercial plant for that purpose.

At that time the Edison direct-current system was very strongly entrenched throughout the country, both because of the great prestige of Mr. Edison and because of the strong financial interests that were believed to be behind him. The Edison Company entirely failed to appreciate the distribution value of the alternating system, and it openly condemned it as dangerous and uneconomical, and prophesied its speedy downfall. For once these noted engineers were mistaken. Of the six thousand sta-

FIG. 7.



tions now operating in this country less than two hundred are furnishing continuous current.

The next step in the development of the art was the devising of the so-called auto-transformer shown in Fig. 7. I worked out this device in the winter of 1886 and 1887; and it is interesting to see that it is almost exactly identical with the arrangement (shown in Fig. 3) that I worked on in 1883, the difference being that, in the latter, two magnetic cores are employed for the two branches illustrated, while in the auto-transformer a single core magnetically links all the circuits together. The auto-transformer has been exceedingly useful in the local distribution of electricity and in regulating the potential of alternating circuits; for example, it is employed in governing and controlling the alternating potential applied to the motors of the New York, New Haven and Hartford Railroad Company's main line system.

The next step in the development of the art was the introduction of the polyphase system by Mr. Tesla in 1887, and the application of the induction motor to commercial purposes. Few people realize the enormous amount of work that was done to develop this invention to its present very perfect form. This motor, whose operation depends upon employing phase differing currents in such manner as to combine their individual fields into a resultant field rotating about one element of the motor, was first devised in 1885 by Prof. Galileo Ferraris, of the University of Turin, Italy. Prof. Ferraris, however, did not appreciate its industrial importance; and, although he clearly described the physical and mathematical reactions that took place, and even suggested that it might be used to furnish the motive power to drive an alternating-current motor, yet he failed to foresee its enormous industrial application. Mr. Tesla, in a number of remarkably clean, clear, and incisive patents, described substantially the same device, and organized it in a practical manner to furnish power from an alternating-current source; yet, several years elapsed and enormous sums of money were spent by the Westinghouse and other manufacturing companies in attempts to make the motor start from rest with a satisfactorily strong torque.

In 1888 I devised another type of motor also employing phase differing currents, and known as the transformer motor, but arranged so as not to produce a resultant moving or magnetic field. This motor was put upon the market by the Stanley Company, of Pittsfield, together with the "inductor alternator" to generate the phase differing currents. My associates were Messrs. John F. Kelly and C. C. Chesney, both well known in the alternating-current art; and together we solved the problem of designing the motor with such electrical constants as to develop a maximum torque at starting.

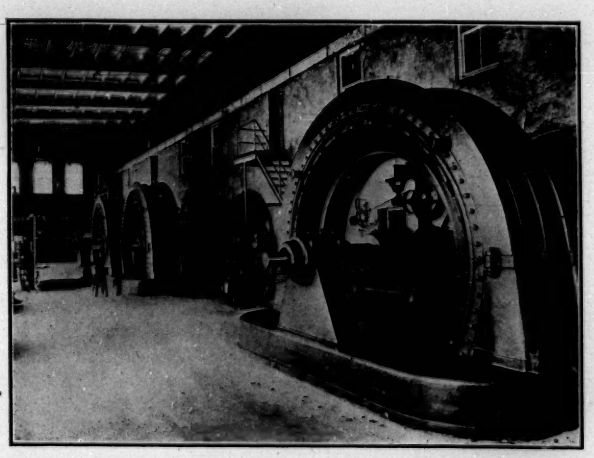
So far as I know, the first transmission of power for industrial purposes by means of phase differing currents was undertaken by the Stanley Company at the village of Housatonic, four miles north of Great Barrington, where power was conveyed from a waterfall over about a mile circuit to the Monument Mills. This plant is still in successful operation. The inductor alternator is still rotating and furnishing power, although during the last year a number of the old transformer-motors have been displaced by those of more modern type.

It is to be noted, however, that power was transmitted over

long distances in Europe, especially by Dobrovolski and C. E. L. Brown at the Frankfort Exposition, before this plant was installed.

Fig. 8 shows one of the inductor alternators employed for transmission work by the Stanley Company. This machine was originally designed in 1887, when models were built at the Great Barrington laboratory. In 1888, with Mr. Frederick Darlington, the well-known traction engineer, I developed a type of alternator for the production of currents of constant volume under varying conditions of electromotive force. All alternating machines so

FIG. 8.



far produced had been made for the purpose of supplying electricity at constant potential. The present machine contained no regulating mechanism whatsoever, but depended for its regulating power upon the proportioning of the fluxes in the two elements, field and rotor.

This alternator performed in a very remarkable manner. When driven by an engine without a governor, or by any variable-speed source of power, and when connected to a series of arc lamps (50, for example) it could be instantly short-

circuited without changing the value of the current in its coils and with a proportionate decrease in the power applied to it; that is to say, it furnished an approximately constant value of current irrespective of the speed of rotation above a certain minimum, resistance, and inductance, in circuit. It was amusing to see an engine *run away* when the machine was *short-circuited* without increasing the potential or current generated. These machines were installed in New York City and other places to furnish current for arc-light service; but this service, owing to the imperfections in the arc lamps employed, did not prove satisfactory.

In 1890 or 1891 the maximum potential employed for distributing electricity by alternate currents was, I believe, about 2,000 volts. Happening to be in Canada at that time, I was asked to advise the Quebec Lighting Company how they had best expand their plant, which was operated from the Falls of Montmorency, about six or seven miles northeast of the city. After looking the subject over, I concluded to install machines at the falls that would generate alternating currents at 5,000 volts potential. This was done, and was the first step towards increasing the transmission voltage.

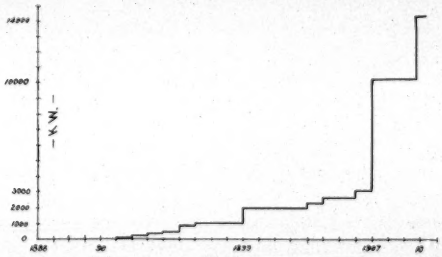
At that time the largest transformers made were 40-light capacity. The engineer of the Westinghouse Company lent the authority of his position to the generally-accepted belief that transformers larger than 2-kilowatts would not be economical, and wrote an elaborate paper to substantiate his position. For more than a year we had been operating at Pittsfield transformers of over 200 lights capacity, or about 10-kilowatt size. So when we offered them to the public we were met by the authoritative assertion of the Westinghouse Company that they must necessarily be inefficient. A few tests by their engineers, however, convinced them that their mathematics were incorrect, and large transformers began to be produced by several makers.

It is interesting to note the growth and size of the transformers employed in transmission work since 1885, and the growth of the potential employed in distributing electrical energy. Figs. 9 and 10 illustrate these two factors.

At about this time, namely, in 1892, Messrs. Kelly, Chesney, and myself, all of whom were most busily engaged on the solution of many problems that I cannot burden you with this evening, determined to find out at Pittsfield if there were any limits in

sight to the use of higher potentials for line distribution than were generally employed. To this end, we erected a pole line on the farm of Mr. Charles Atwater, then president of the Stanley Company, built a shanty, or transformer house, and set up some transformers, which increased the potential of the town circuit from 1,000 to 15,000 volts, connected the line to this high potential supply, conveyed the current around the farm and back to the same transformer house, and then transformed it down to 1,000 and again to 100 volts to operate banks of lamps that represented our distribution load. This system was operated during a Berkshire winter for the purpose of finding out if the insulators would stand the strain imposed about them. As the result of this work Messrs. Chesney and Kelly, in the following year, advocated the first real high transmission voltages that were

FIG. 9.



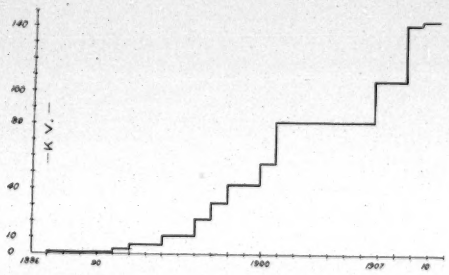
employed in this country, increasing them from 15,000 to 25,000, next to 30,000, and, finally, to 60,000 volts; and under their direction the famous Blue Lakes plant of California was constructed, whose generating station produced alternating currents at 60,000 volts pressure and conveyed them over a maximum distance of 240 miles.

Engineers of this country owe an enormous debt of gratitude to the courage of these two men, who, in spite of the opposition of strong financial interests, yet boldly prophesied and successfully introduced the use of very high potentials for the distribution of electricity over long distances.

The Blue Lakes plant was but the first of dozens of other plants of a similar character that have been installed and that are now taken as a matter of common engineering experience.

It is to be remembered that four or five such plants could supply a belt of country from the Atlantic to the Pacific 500 miles wide, furnish electricity to move all the mechanical appliances, including traction service, and, further, light every community that lay in their path. Indeed, it seems very likely to me that in the not far future, after we have determined how far it is best to entrust our public service to the community at large, the State will run electrical highways throughout the land for the purpose of placing electricity in the hands of the public at a very reasonable price. I have seen the estimates of a distinguished engineer that clearly

FIG. 10.



prove to me that the entire State of Illinois can be supplied with electricity from three interlinked stations, and that these stations would not only supply the State of Illinois, but would lap over into the neighboring States and cover a territory nearly as large on its borders.

Such, then, is a part of the story of the development and growth of the alternating system in this country. It seems a long step from the limitations of 1884 and 1885, when the maximum area served was approximately sixteen square miles, to the present service obtainable from a central source that will furnish at equal efficiency an area of 400,000 square miles. Yet I presume that the advances of the future, if they are not in the same lines that we have followed in the past, will create an equal impression in the development of the art until future generations will take their supply of electricity in the same manner that they take their water and air supply; that is, as a gift of nature.

THE ELECTRIFICATION OF MAIN LINE RAILROADS.[1]

BY

WILLIAM J. CLARK,

New York.

CERTAIN general characteristics are common to railways of every description, but each road has its own peculiar conditions, which differ from those of every other.

Such variations exist not only between different roads, but also between parts of the same property; and the larger the system, the more pronounced they are.

The problems presented by these differences in physical, financial, and traffic conditions, with their innumerable combinations, are complex.

How to solve them, so far as it can be done by steam operation, is comparatively well understood through long experience. Moreover, the limitations of this form of operation tend to simplify the methods of its application.

Electrification presents new possibilities of solution, and offers a wider range of operative methods. Which or what combination thereof should be used requires great engineering skill.

There are differences in engineering opinion on these features. All agree, however, that the electrification of any railroad should be viewed as a distinctive engineering and financial proposition, and that all of the attendant conditions should be carefully considered before electrification is decided upon or the form of its adoption determined.

Somewhere, and in some manner, practically every problem that may be involved in the electrification of almost every railroad has been solved, or at least sufficient experience has been obtained to determine the proper solution.

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[1] Presented at joint meeting of the Electrical Section, the Philadelphia Section, American Institute of Electrical Engineers, and the American Society of Mechanical Engineers, held Thursday, March 7, 1912.

It is impossible to set forth all of this experience or give much of its detail in a paper of this character.

Descriptions of nearly all the important electrifications of steam railroads have been printed by the technical press. Numerous papers of similar purport have been read before scientific and other bodies, and a few statistics of costs and results from operation have been made public.

It is desired to avoid mere repetition of the same so far as possible.

The experience secured with any particular installation, as already indicated, cannot be advantageously duplicated in its entirety elsewhere.

Nevertheless, each of its distinctive features, wherever obtained, has its value in determining the advisability of further railway electrifications and what their proper forms should be.

Consequently this paper will attempt to state only in a general way some of the things that electric traction has accomplished, and the bearing which these have upon the electrification of main line and other railroads.

The coming electrification of main line railroads is principally dependent upon the percentage of net earnings secured to the capital investment therein, without regard to attractive features, excepting as they develop passenger traffic, or so facilitate freight movement and delivery as to increase its volume and consequent earnings.

So far as railroad electrification has progressed, it has shown that the closer it approaches the form of what is considered to be main line operation the more successful it is.

But just what a main line railroad and its service was, now is, or will be in the future is difficult to definitely determine.

The extent, character of service, and possibilities of steam railroads, in their earlier years, were vastly different from those of the present.

A glimpse of these conditions is afforded by the following extracts from the writings of Ezra C. Seaman, an economist of sixty-five years ago.

Referring to American and European steam railroads, he states: "Their profits are mostly derived from the transportation of passengers, carrying of mails, and tolls on valuable mer-

chandise. But a small portion of it comes from tolls on raw materials and products of agriculture."

"They should follow population and business and not attempt to penetrate the wilderness in advance of them."

Again: "The greater part of agricultural products are so cheap in proportion to their weight and bulk that very few, if any, railroads can yield much profit if their principal income is derived from the transportation of such articles."

The same writer fixes the minimum market value of two cents per pound upon commodities as a figure below which their transportation by railroad would not be warranted.

He shows that in 1845 the passenger earnings of the lines which now constitute the New York Central system from Albany to Buffalo, aggregating 326½ miles of track, were $1,061,255; those from freight but $129,094—a very small proportion of the total earnings, as should be noted.

In all probability, from 1845 to 1850, main line service would have been considered transportation between the terminals of any of the several distinct roads which made up the then existing rail connection between Albany and Buffalo.

The greatest length of track owned by any of these railroad companies was only 78 miles.

Probably the longest distance between the terminals of any steam railroad in the United States at that time was about 150 miles.

About thirty years ago, a thoroughly conscientious president of the New York, New Haven and Hartford system, testified, under oath, that the traffic of his system, especially its freight business, was, and must always be, local.

The present idea of a main line railroad is doubtless the main stem, at least, of an extensive steam railroad system over which through service is operated.

Yet no matter how long or important such a stem may be, through service thereon, in its strictest sense, is limited to the longest possible continuous run of a steam locomotive; for, while undivided trains proceed over its entire length and beyond, the locomotives which haul them do not.

Looking well to the future, it is within the bounds of possibility that ultimately nothing short of the through opera-

tion of undivided train units, including locomotives, from coast to coast, or from the Lakes to the Gulf, may be considered main line or through service.

Possibly this same general theory may take another form; such, for instance, as the nucleus of an extensive multiple unit train, starting for a long continuous run and alternately picking up additional cars or dropping them at stations or branch line junctions without stopping.

Automatically-operated freight railways may also appear, these to connect great centres of freight traffic creation, such as ore beds or coal mines, with shipping points or great cities.

They would certainly constitute a distinctive type of purely main line railroad, ideal as to moving an enormous tonnage at a minimum of expense.

It is probable that in the very near future the paramount reason for the electrification of steam railroads will be to more advantageously operate their freight traffic, and the well-recognized advantages of electric traction in passenger transportation will then be considered only as an incidental benefit.

Within a few years the motor vehicle may transport upon the highways, for equal or longer distances, a goodly portion of what is now considered to be main line freight traffic.

Relative to this phase of possible development, a report made to the Association of Edison Illuminating Companies in September, 1911, by a Committee on Electrical Vehicles, states: "It is a fact that sixteen times as much freight was hauled on roadways as on railroads; that is to say, the tonnage of trackless haulage in this country is sixteen times that of track haulage."

There is no question but that the development and adoption of electric traction upon rails, of electrical and mechanical methods for handling commodities at terminals and warehouses, and of the motor vehicle, will together work radical changes in freight handling and transportation from the points of its origin to that of its ultimate delivery. In addition, it will greatly reduce the expense of transportation and incidentally modify ideas as to what through or main line traffic is.

But, returning to better established conditions, the constant tendency in steam railroad operation has been, and still is, toward larger units on every feature incident to locomotives, cars, and trains.

Electric railway operation has developed two distinctive operative forms: one the highly efficient small unit, adaptable to a very wide range and character of service; the other the most powerful locomotives that can be produced.

The experience obtained with the first has been of immense value in the production of the other, and is equally so in determining the future possibilities of steam railroad electrification and operation.

A brief outline of what has been accomplished by and with the small units is of interest, hence what follows:

American railway statistics have always ignored mining and nearly all other forms of industrial railways. Nevertheless, systems of this character have been an important factor in freight transportation for many years.

The first electric mining locomotive in this country began its operations in 1887, but the introduction of electric traction on a commercial scale in the mining field commenced in 1889 or 1890.

At least two electric locomotives then placed in operation are known still to be in daily use.

There are at present over 10,000 electric locomotives operated in this country upon railways of the general character stated. They range in capacity from a few horsepower each to the equivalent of that possessed by steam freight locomotives employed in main line service.

Their number is increasing at the rate of nearly 1,000 per annum.

The total tonnage now hauled by these electric locomotives probably amounts to over one-third of the entire freight tonnage of all American steam railroads. The length of haul, however, is comparatively short.

Despite this last-mentioned condition and the small capacity of the locomotives and cars principally employed in such service, many instances exist where the cost of such haulage per ton mile approximates the low figure of one cent, including maintenance and depreciation.

Results from the electrical operation of mining and industrial railways have shown that the investment therein is fully warranted, and incidentally has taught a fundamental lesson that

applies with equal force to the electrification of main line and other railroads; *i.e.*, that the standards by which the investment therein should be gauged are those of net efficiency and the greater flexibility provided, not the comparative price of steam locomotives by weight.

Among the class of railways now under discussion should perhaps be included a comparatively new and distinctive type of electric main line railroad—that designed for towage on canals.

Various experiments of this nature have been made in this country, and a few comparatively small installations are operated in Europe.

That designed by Col. Edward Schildhauer for the towing of vessels through locks of the Panama Canal is the most extensive and original that has yet been undertaken. Forty large electric locomotives and other essentials to operation have already been contracted for.

As the vessels will be towed at the rate of only two miles per hour, a natural query may be, What has such a service in common with the electrical operation of a main line railroad?

The answer is: Securing, at least, the advantages of such an accuracy and reliability of control, in moving enormous weights, as could not be obtained by mechanical means.

Turning now to forms of railways that are officially recognized by American National and State authorities:

Their general classification has never been absolutely correct, and the difficulty of avoiding incongruities therein has greatly increased during recent years, which also affects the determination of what main line roads are.

The following grand divisions have, however, been officially established and are usually adhered to by National and State authorities in this country:

"Railroads," which signifies steam railroads.

"Street Railways," changed in recent years to read "Street and Electrical Railways."

Simple as such classification would seemingly have been twenty-five years ago, there were even then over 700 miles of steam-operated track included in the enumeration of street railways.

Some of this was located upon its own right of way, and a small quantity of freight was transported thereon.

Certain of this same trackage was owned or controlled by steam railroad companies, and virtually constituted parts of their systems.

Steam locomotives and dummies to above 600 in number have been superseded by electric traction upon lines of this character formerly operated by steam, and in every instance better net financial returns have resulted.

The following changes have come in the general character and extent of so-called street railways since the census of 1890:

There were then 5,661 miles of horse railway track. In 1907 only 136 miles remained.

In 1890, cable operated, 488 miles. In 1907, only 62 miles.

In 1890 the trackage of surface electric lines was 1,262 miles. In 1907 it had increased to 33,983 miles, and is now above 41,000 miles.

In 1890 there were 569 miles of steam-operated surface lines. In 1907 this had decreased to 62 miles.

In 1890 the total trackage of elevated railways was about 152 miles, all steam operated. In 1907 there were 420 miles of elevated and subway track, all electrically operated, and this total is now above 500 miles.

These changes, so briefly stated, only partially indicate the difficulties in reaching a determination, from official classifications, as to what a railroad, main line road, or street railway may be.

There are 8 roads designated as railroads in the United States which have but 1 mile of track each; 19 with but 2 miles; 25 with 3 miles; 16 with 4 miles; 40 with 5 miles; 18 with 6 miles; 35 with 7 miles; 29 with between 7 and 8 miles.

Among a total of approximately 125 well-defined types of interurban electric railways, the smallest trackage reported by any is one with 17 miles and another with 20. All the rest have 30 miles or over, and several of the larger systems operate from 200 to 450 miles, respectively.

Approximately 18 railroads have their electric sections or divisions.

Ten other railroad properties operate what is considered to be a mixed steam and electric service.

Large railroad systems own or control several thousand miles of street and interurban electric railways.

In about thirty instances electric railways have leased, and electrically operate, portions of steam railroad systems.

Electric railways have thus invaded and expanded the transportation field which main line and other steam railroads alone occupied in the past, as is evidenced by what follows:

They operate both freight and passenger trains in regular service, weighing as high as 500 to 600 tons each.

The proportion of freight rolling stock to passenger equipment on some is greater than that of many so-called steam railroads, and their traffic is of a corresponding character.

One in the Far West has a badly overcrowded freight terminal, with a capacity of 1,800 cars, and is now constructing another to care for an additional 3,500 freight cars.

Similar conditions, differing only in extent, exist in connection with a large number of other systems.

About one-third of the total trackage of all these railways is located upon its own right of way.

The average weight of rail is probably heavier than that laid by the steam railroads, and it is said that nearly the same proportion of track is equipped with block signals as on the railroads.

Longer unbroken trips in the same cars can be made than was possible upon any steam railroad in the United States a few decades ago, or now is upon many.

Connecting lines and cars make continuous trolley rides possible for many hundreds of miles.

Through bills of lading on freight are issued by numerous roads.

Several of these operate express passenger train service, for long distances, at higher speeds than do competing steam railroads to the same points.

Chair, dining, and sleeping cars are found among the rolling stock of these roads.

A number have imposing passenger stations in the hearts of large cities, as well as modern local stations.

Most of the power-equipped rolling stock of the electric railways, however, consists of motor cars; yet, viewed from an

operative stand-point, and not by the form of its superstructure, every electric motor car is a locomotive which can be operated alone or with trailers, and in trains intermixed with other motor cars and those not so equipped.

Out of a total of above 75,000 of these motor cars operated by American electric railways, at least 20,000 can exert a greater tractive effort than an equal number of steam locomotives that are in railroad service.

Most of these high-powered cars have M. C. B. couplers and Standard air brake equipment.

Some other features and problems of importance in modern railroad operation have also been worked out by the electric railways which place them in advance of the railroads.

For instance, it is an almost forgotten fact that the paramount reason for the original introduction of electric traction on surface railways was to operate lines located over heavy grades, where the great cost of cable construction, equipment, and operation was prohibitive.

The following tabulation confirms this statement:

Number of electric roads reporting their ruling gradients in 1890.	Maximum per cent. of grade.
1 with	15.48
2 with from	12 to 15
3 with from	10 to 12
66 with from	5 to 10
42 with maximum of	5 or under

If the writer's memory is correct, there was not one of these last mentioned but which had maximum grades of well above two per cent.

As thus shown, it was early recognized in electric railway practice that it was wiser to make capital investment for electrification than to incur still heavier expenditures for so reducing ruling gradients as to permit operation by steam or some other motive power.

Strange to say, the value of this practice is not yet thoroughly grasped by all railroad financiers, managers, and engineers.

Within the past few months, however, two surveys of a proposed railroad, about 160 miles long, located through a

rough mountainous region, have been made: one to grades that would permit of steam operation; the other to those which can be easily and economically operated by electricity.

The saving on capital investment, estimated by the locating engineers on only 6½ miles of this proposed line, is more than sufficient to offset the cost of electrifying the entire 160 miles. Their estimates on the expenses of electrical operation were also less than those for steam.

Many millions of dollars have been expended by railroads to reduce ruling gradients, especially upon their main lines, and enormous expenditures for the same purpose are contemplated.

Needless to remark that when such conditions are to be met the adoption of the practice outlined would, in almost every instance, greatly improve the net financial results secured from main line railroad operation and better the service thereon.

Another fundamental discovery made by the electric railway is that the first essential to be considered in railway electrification is the source and cost of its current supply.

Experience obtained in the operation of electric railways, central stations, and hydro-electric plants demonstrates that the more thoroughly current produced in any electric power station or set of stations is diversified in the forms of its utilization, the cheaper it can be generated and the less will be the cost to the user.

Recognizing this fact, many electric railways have consolidated with power-producing companies, or are furnishing electrical current for all kinds of purposes.

The perfection of such methods for power generation and utilization has been attained by Mr. Samuel Insull, of Chicago.

Taking a leaf from his book: A large railroad has planned to furnish current to others for lighting and industrial purposes, the net revenue from which will be more than sufficient to offset the entire operating expense of its generating stations, which were primarily intended for railroad operation only.

An incidental benefit arises from the fact that cheap electric power, where it is available, encourages the location and expansion of industries, and consequently increases railway traffic.

Electric roads have also shown how to utilize in a profitable way every foot of expensive real estate required for city terminals and passenger stations.

That their example in this respect has been followed elsewhere is illustrated at the New Grand Central Terminal and the McAdoo Terminal Buildings in New York City.

Electric railways have demonstrated lower maintenance costs on buildings, machinery, and rolling stock than has ever been heard of in steam operation.

They have shown how to obtain more revenue service out of the same amounts of transportation wages, and have eliminated widely-distributed sources of water and fuel supply. They have also proven their ability to operate the same weight of trains in the coldest weather with the same tractive units.

They have made it possible to avoid the haulage of unnecessary dead weight.

They attain higher rates of acceleration in ordinary service than can be secured with steam under any conditions, and have proved the now universally conceded fact that electrical operation is far more reliable than steam, and reduces the number and length of service delays.

Before discussing their financial conditions, the following illustration of a phase of past conditions should be given, because it is analogous to one of the present:

Cable railways.	Early electric railways.	Years when opened for traffic.
1	—	1877
1	—	1878
1	—	1879
—	—	1880
—	—	1881
2	—	1882
2	—	1883
—	—	1884
4	—	1885
4	2	1886
6	6	1887
11	30	1888
9	57	1889
7	49	1890[1]
—	—	
48	144	

[1] First six months.

As is thus made apparent, the great majority of cable installations were undertaken after the possibilities of electric

traction were realized, and continued after they had been demonstrated as facts.

A similar attitude is now assured by certain "railroads" which purchase expensive steam locomotives of unusual type to meet traffic requirements on high grades, or expend many millions of dollars upon terminals and stations designed for steam operation only.

Now turning to the financial side of the situation: The showing of street and electric railways in statistical averages of capitalization, and its earnings, has been affected by causes other than electrification, *per se*, some of which should be stated.

Prior to the introduction of electric traction the capitalization of all forms of street railways was much above their officially reported costs.

The sale and resale of many city properties since then, and their frequent consolidations, have enormously increased their capital accounts.

The Census Report of 1890 states that "the greater part of the electric roads are either suburban or serve the people of comparatively small cities."

Their road-beds were then light, and but little paving expense had been involved, although it has since become one of the largest items that go to make up the total cost of electric railway construction in cities.

The rolling stock principally consisted of electrified horse-cars or their equivalent, long since superseded.

Since that period, constant advancement in the art has caused frequent increases in size, weight, and motor capacity of cars, and the abandonment of existing types, to be superseded by others. Similar experience has also been had with every other essential required to secure improved electrical operation.

The early state of the art, and failure then to appreciate the future growth and requirements of traffic, are accountable for the original investment in things that have been discarded. Public demand for better transportation facilities, however, is responsible for the scrapping of what that investment represented and the increase in capitalization which necessarily followed.

Nevertheless, it has been proven that it is advisable, in electrical transportation, to set aside present plant in which there

is a large investment and make a further large initial expenditure, to provide entirely new equipment, in order to obtain larger earnings from operation.

As affecting earnings, it should be stated that, from the first, railroads have most properly proportioned their transportation charges to the services rendered, basing them upon passenger and ton mile rates.

Against this, street and electric railways, excepting the interurbans, have adhered, and do adhere, to a flat passenger rate, no matter what the length of passenger ride may be.

As the average length of rides has doubled within twenty years, it is obvious that this method has seriously affected their net earnings.

The average fare received per passenger in 1890 on surface street railways, in accordance with their method of operation, was, approximately:

Animal	4.75 cents
Cable	4.43 cents
Electric	4.84 cents

This averaged 4.3 cents on all surface electric roads in 1907.

The approximate capitalization per mile of track, and net earnings from operation thereon in 1890, were as follows:

	Capitalization per mile of track.	Percentage of net earnings on capitalization.
Animal	$ 38,466	4.7
Cable	175,595	1.5
Electric	28,569	2.6

In 1907 the average capitalization per mile of track of all surface electric railways was $95,770. The percentage of net earnings on the capitalization was 4.72.

The creation of traffic through the attraction of electrical operation, coupled with its net economy, is, of course, responsible for this last result.

One feature of this is made apparent by showing the average number of passengers annually carried per car. In 1890 this was:

Animal	54,791
Cable	61,610
Electric	46,600

In 1907 this averaged, for all surface electric railways, 135,576.

Another feature is the increased annual mileage per passenger car. In 1890 this was:

Animal	12,738
Cable	12,798
Electric	14,967

In 1907 the average mileage per passenger car was 24,084.

Although this last is the average of a total service, principally operated through city streets, it is approximately 20 per cent. higher than the revenue miles of steam freight locomotives on the railroads, and about 60 per cent. of the similar performance of steam passenger locomotives.

For comparison on this feature it should be stated that the annual revenue mileage of steam passenger locomotives increased from 30,721 miles in 1890 to 39,923 in 1907; but the similar performance of steam freight locomotives decreased during this period from 25,465 to 20,121 miles.

The earnings from the transportation of freight, mail, and express by the street and electric railways grew from a few thousand dollars in 1890 to about $7,500,000 in 1907, and it is said that the total of these earnings in 1911 was over $15,000,000.

The one distinctive type of properties enumerated among street and electric railways whose progress can be most accurately traced between 1890 and 1907, and afterward, is the elevated roads. All of these were operated by steam in 1890, as were others which came into existence afterward. In the census of 1907 the operations of subway railroads were included with those of the elevated lines.

The average fare received per passenger on all elevated railroads in 1890 was 5.02 cents. Upon all elevated and subway roads in 1907 the corresponding figure was 4.93 cents. In 1890 the average capitalization per mile of track of all elevated roads

was $561,124, and the net earnings from operation average 5.5 per cent. thereon.

In 1907 the similar capitalization of elevated and subway railways was $639,668, and the average percentage of net earnings from operation on this amount was 7.03.

The financial betterments which have come to this class of properties through electrification are more clearly illustrated by giving brief glimpses of what has occurred on certain individual properties of this character.

According to the report of the New York Railroad Commissioners in 1890, the capitalization per mile of track of the properties constituting the Manhattan Elevated System of New York averaged $663,318, and the percentage of net earnings from operation on capitalization was 7.2, the total earnings being $4,448,477. The system then carried 189,974,848 passengers.

In 1901, just prior to electrification, the Railroad Commissioners' Report states the similar capitalization as $800,162, and the percentage of net earnings from operation thereon, 4.8, the total of such earnings being $4,163,658. The total number of passengers carried was 190,045,741.

In 1904, after the first year of full electrical operation, the report of the Railroad Commissioners does not clearly state the amount of capitalization, but it does show that the percentage of operating expenses to earnings from operation had decreased from 55.79 in 1901 to 41.2 in 1904, and that during the same period the net annual earnings from operation increased from $4,163,658 to $8,683,139. The number of passengers then carried was 286,634,195.

The annual report of the Interborough Rapid Transit Company for the year ending June 30, 1911, gives the percentage of operating expense to earnings from operation in that year, on the Manhattan System, as 41.8, and the total net earnings from operation, $8,974,617. The total number of passengers carried was 301,449,292.

In this connection it should be remembered that since 1904 the company which now operates the Manhattan System has developed the competing subway system, which in the year ending June 30, 1911, carried 276,704,796 passengers and earned net from operation, $8,423,553.

The report of the New York Railroad Commission in 1890 gives the average capitalization per mile of track on all of the elevated railroads in Brooklyn as $434,905. Their total net earnings from operation were $802,416, which average 2.2 per cent. upon their total capitalization. The total number of passengers then carried was 45,207,410.

The report of the commission for 1898, issued shortly before the electrification of these properties, showed their capitalization to average $612,535 per mile of track, and their total net earnings from operation as $625,228, which averaged 1.4 per cent. upon their total capitalization. They then carried 44,170,810 passengers.

Owing to the reorganization, leasing, etc., which have occurred in connection with these properties, the writer is unable to state their capitalization from public records since that time, but the report of the Public Service Commission for 1909 shows that their net earnings from operation had increased to $2,248,509 and the total number of passengers carried to 146,950,607.

The elevated railroads in Chicago have shown equally remarkable results from their electrification.

The net annual earnings of the South Side Elevated, immediately before its electrification, were but $133,029. Immediately thereafter these increased to $500,448. In 1910 these were $803,978, or 4.4 per cent. on the total capitalization.

On the Lake Street Elevated, the predecessor of the present Chicago and Oak Park System, in 1895, when it was operated by steam, 9,936,450 passengers were carried. In 1904, when operated by electricity, it carried 16,205,328. Operating expenses had also decreased 8.2 per cent. during this period.

Referring more directly to the electrification of "railroads"—so termed: Electric railways have assumed their functions more rapidly and to a greater extent than main line or other railroads have been electrified.

A long list of former steam roads and branches that are now electrically operated could be given, but the greater portion of these are less entitled to qualify as main line railroads than a very large number of the so-termed electric railways.

The larger electrification projects of American steam railroads that required especial mention are these:

Railroad system	Location of Electrification	No. motor cars	No. locomotives	Total miles of track	Remarks
Boston & Maine	Hoosac Tunnel	..	5	22	Main line tunnel operation. Weight locomotives, 130 tons or more each
N. Y., N. H. & H. R.R.	New York to Stamford	4	45	100	Main line passenger operation. Weight locomotives, 80 to 140 tons each.
N. Y., N. H. & H. R. R.	Providence, Warren, and Bristol	77	..	33	The equivalent of a high-class interurban electric.
N. Y. C. & H. R. R. R.	Grand Central Terminal Lines	137	47	143	Terminal operation and multiple unit suburban service. Weight locomotives, 95 to 115 tons each.
N. Y. C. & H. R. R. R.	West Shore	21	..	114	High-speed multiple unit passenger service.
Pennsylvania Railroad	Long Island R. R.	588	..	164	Multiple unit passenger service.
Pennsylvania Railroad	New York Terminal	..	35	11.89	Terminal operation. Weight locomotives, 157 tons each.
Pennsylvania Railroad	West Jersey & Seashore	93	..	150	Multiple unit passenger and mail service.
Erie Railroad	Rochester Mt. Morris Div.	..	6	40	Branch line freight and passenger service. Weight locomotives, 48 tons each.
B. & O. R. R.	Belt Line at Baltimore	..	12	10	Main line tunnel service. Weight locomotives, 96 to 160 tons each.
Michigan Central Railroad	Detroit River Tunnel	..	6	19	Main line tunnel operation. Weight locomotives, 100 tons each.
Grand Trunk Railroad	Sarnia Tunnel	..	4	12	Main line tunnel operation. Weight locomotives, units, 66 tons each, two operated together.
Canadian Pacific Railway	Aroostook Valley R. R. (Maine)	12	2	12	Service equivalent high-class interurban.
Great Northern Railways	Cascade Tunnel	..	4	6	Very heavy main line freight and passenger tunnel service. Weight locomotives, 115 tons each.
Southern Pacific Company	Oakland-Alameda Lines	65	..	100	Very heavy multiple unit suburban passenger traffic.

It is regretted that but few comprehensive figures are available upon the financial results secured from any of these electrifications, but the following is an indication of what is being accomplished in connection therewith:

NEW YORK, NEW HAVEN AND HARTFORD RAILROAD.

New York to Stamford:

That electric operation has been found satisfactory from a financial stand-point is best evidenced by the decision of the company's President and Board to undertake extensions of electric service, not only on their main line, but elsewhere. Their immediate plans in this regard are broad and far-reaching.

NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

Grand Central Station:

This installation is not fully completed, in accordance with the original plans, which fact has naturally prevented the results from operation appearing quite so favorable as they will ultimately be.

Since the electrical service was inaugurated, five years ago, it has been operated under probably the most harassing and perplexing experiences, from exterior causes, that have ever occurred in handling one of the most dense train movements in existence. This because of the rapid and constant construction changes at the Grand Central Terminal.

Track locations and grades have been shifted many times in a single year, which have necessitated corresponding changes in the location of transmission cables, working electrical conductors, signalling apparatus, etc.

Despite these conditions, the reliability of train service has constantly improved, and at all times has been superior to the previous steam service in that respect.

Such a combined triumph of construction, engineering and skillful terminal management has rarely, if ever, been seen.

No figures showing operative results have been made public since those given in a paper by Mr. W. J. Wilgus in March, 1908.

It is understood, however, that considerable improvement has since occurred on all phases of operation.

Mr. Wilgus states the respective annual costs of service available from each steam and electric locomotive, including interest on their cost, depreciation, repairs, inspection, and handling, to be; For steam, $4,460.50; electric $3,679.00; annual saving of electric over steam, $781.50, or 19 per cent.

He summarizes the advantages of electric locomotive operation as follows:

19 per cent. saving in locomotive repairs and fixed charges, the effect of which has already been shown.

18 per cent. saving in dead time for repairs and inspection.

25 per cent. greater daily ton mileage.

6 per cent. saving in locomotive ton mileage in hauling service.

11 per cent. saving locomotive ton mileage in switching service.

16 per cent. saving in locomotive ton mileage in road service.

12 per cent. net saving in cost of hauling service.

21 per cent. net saving in cost of switching service.

Mr. Wilgus has thus furnished a basis for calculation upon what can be expected from the substitution of electric for steam locomotives on a large scale which, if followed to a logical conclusion, gives startling figures upon attainable economies, improvement in service, and net financial results in heavy railroad operation.

It is to be regretted that he did not give much information upon the results secured from the operation of multiple unit cars. If, however, they are proportionate to those secured by the Long Island Railroad from multiple unit operation in like suburban service, the net financial gain therefrom would alone justify a large part of the New York Central's total expenditures for electrification.

PENNSYLVANIA RAILROAD.

West Jersey and Seashore:

Mr. B. F. Wood, in an admirable paper of last August, states the total cost of its electrification to be $8,130,229, and that in 1910 4,552,532 car miles were run at an average cost of 18.19 cents.

Mr. George Gibbs, in another paper, states that the average cost per car mile for steam service on this road was 22.3 cents, consequently a saving in favor of electricity is shown of 4.11 cents per car mile, giving a total of $187,109 saving in this regard. This, however, is not the whole story, for traffic increased enormously as a result of electrification. It is said that prior thereto the net earnings from operation were practically *nil*, while the net earnings in 1910 were about $700,000.

Long Island Railroad:

Mr. Ralph Peters, president of this company, in his annual report for 1910, states: "The results obtained from the operation of your electrified lines continue satisfactory, both from the standpoint of economy and increased business."

In a discussion before the New York Railroad Club on March 19, 1911, Mr. James McCrea, general superintendent, strongly confirmed the above statement in detail.

Mr. George Gibbs, in his paper presented before the International Railway Congress in 1910, gives much of interest concerning the results secured from the electrification of the Long Island Railroad.

He says that in 1908 the total operating expenses per car mile average 17.8 cents, against a cost of 27.95 cents by steam, demonstrating a saving of 10.15 cents per car mile by electricity. The total electric car mileage is given as 4,662,230.

It will be noted that the consequent saving from operating this mileage electrically was $473,216.

Pennsylvania Railroad:

Mr. George Gibbs, in another paper, presented before the American Society of Civil Engineers, May, 1911, states:

> The Pennsylvania began operating trains to and from the station on November 27, 1910, and in the first ten months of operation the average number of train movements in and out of the station each day, including Long Island Railroad trains, was 430. The average number of locomotive movements per day was 290. The number of passengers carried by Pennsylvania Railroad trains was 31 per cent. greater at the end of the ten months than during the first month after operation was begun. The increase in number of passengers carried on Long Island Railroad trains was 92 per cent. During the past seven months the passenger receipts of the

Long Island Railroad have increased 161 per cent. There have been no delays whatever to trains by reason of failures of the power supply in the power-house or in the transmission system. There have been only three delays caused by current being off of one or more sections of the third rail. During the same period there have been only four locomotive failures causing delays to trains. The electric locomotives ran 189,000 miles per failure, and the miles run per minute of train detention due to locomotive failures were 75,000.

The principal reasons why much more electrification of main lines and other railroads has not been accomplished in this country are generally considered to be these:

First. That as a result of political agitation the railroads for several years have been so harassed by National and State authorities as to make it difficult for them to raise additional capital required for electrification or any other important betterments.

Second. The "battle of the electrical systems" which has raged among electrical engineers.

Third. Past traditions and conservatism prevailing in railroad circles.

That the first is paramount to the others is indicated by what immediately follows:

Such governmental attacks upon the railroads are unknown in other countries.

The "battle of the systems" now rages there even more fiercely than here.

American railroad men are universally conceded to be the most progressive in the world.

The United States has outstripped all other countries combined in the development of local and interurban electric railways.

Yet more electrification of main line and other railroads has been accomplished and is in progress abroad than here. The principal cause is therefore obvious.

Time and space are not now available in which to describe the progress of railroad electrification in other countries at great length, but it is briefly as follows:

Several important projects of this character are about to be undertaken in Canada.

In Cuba the Havana Central Railroad, a system with 73

miles of track, operates twenty-five large motor cars and ten 50-ton electric locomotives.

It is doubtful if any railroad of the same length and similar surroundings in this country enjoys so heavy and profitable freight and passenger traffic.

It probably affords the first instance in the world where a full-fledged standard railroad was designed and constructed, from the ground up, for electrical operation.

Decision to adopt this course, instead of constructing a steam railroad, was determined by the cost of establishing and operating water stations for steam locomotives, with their expensive upkeep and high cost of locomotive maintenance that would be occasioned by the corrosive action of the only water available.

Subsequent experience has demonstrated that all other features of operating expense were much below the original estimates thereon, and that the greater flexibility of service afforded by electric traction has developed freight and passenger traffic far above expectation.

In conservative Great Britain, the experiences with electrification of tramways, and on local lines at London and elsewhere with a service similar to our subways and elevateds, have been equally favorable to that secured in this country.

The most important railroad electrifications there are those of the North Eastern, radiating from Newcastle-on-Tyne; the Liverpool and Southport Division of the Lancashire and Yorkshire; and local lines of the London, Brighton and South Coast, closely adjacent to London.

The managements of all three of these properties have repeatedly made public announcement to the effect that the financial results from their operation were most satisfactory.

Although the comparative capitalization of British railroads is much higher than that of American roads, nearly all of the larger British systems are now seriously contemplating more or less extensive electrification.

Germany has already accomplished much in the same direction, the results from which are officially certified to as warranting the necessary capital expenditure.

Notably high-speed records have also been made upon German electrified roads.

France has had conspicuous railroad electrifications for a

number of years, the most important being those of the Paris and Orleans; Paris, Lyons and Mediterranean, and The Western of France, at and in the vicinity of Paris. The results secured from the operation of all of these have been officially and frequently stated to be satisfactory, and it is said that each and all of these electrifications will soon be extended.

The Southern or Madi System, one of the most important in France, has already commenced to electrify several hundred miles of its trackage.

Austria, Sweden, and Norway have undertaken railroad electrification, and reports from each and all indicate favorable financial results.

Italy and Switzerland have accomplished still more, with equally favorable results.

Probably these two countries afford the best existent illustrations of strictly main line electrification through operation of long tunnels and contiguous service.

The most important is, perhaps, the Giovi Line, which constitutes a goodly part of a main transportation artery extending from Genoa (the nearest available seaport) to one of the greatest and most rapidly growing industrial districts of the world, Lombardy.

The physical conditions of the road are very similar to those of certain American transcontinental lines in the mountainous regions of the Far West, excepting that the tunnels are more numerous and located closer together.

The freight traffic is equally heavy and dense. In the past the train movements by steam were as frequent as the ventilation of the tunnels would permit.

The rapidly-increasing traffic necessitated either electrification or the construction of a parallel steam road. The former course was adopted because of the enormous expense involved in the latter. But it is officially stated that the financial result secured from electrical operation has demonstrated that its cost was well warranted without regard to the reason which caused its adoption.

This situation is analogous to one in this country where it was desired ultimately to increase the train movements on a certain mountainous division, and concerning which a lately-deceased prominent railroad president tersely remarked that it

was either a question of taking two years' time and expending $8,000,000 to electrify the division, or of devoting eight years to the construction of a new route for steam, which would cost $40,000,000, and then electrify, if it was to be operated economically.

In conclusion, the hope is expressed that this paper has demonstrated the following:

Conditions of no two railways are identical.

Electrification of each or all requires careful engineering consideration.

The adoption of electrification is principally dependent upon the financial results attainable therefrom.

It is difficult to exactly define a main line railroad.

"Railroading" is "railroading," no matter by what motive power it is accomplished.

The small unit is an important factor in perfecting rail transportation methods.

That the comparatively high capitalization of street and electric railways is not entirely attributable to electric traction.

The financial results obtained from electrical operation of all kinds and types of railways justify its more general adoption by the steam railroads.

That political and governmental agitation is principally responsible for America not having made greater advancement in this last-mentioned direction.

DISCUSSION.

MR. WOOD: I cannot add anything to what Mr. Clark has said; in fact, he has said it all; he wound up by taking away all the ammunition I had. There were, however, a few things that I may allude to. Mr. Clark gave three principal reasons for the electrification of railroads, or, rather, why electrification has not made more progress than it has done. The first one was on account of political influences, and the second, the battle of systems. In my opinion, it is more a battle of systems than political influences, and I think the retardation of the development of the electrical railway is largely because there was only one system; that is, there was only the direct-current system at that time. It strikes me it is up to the electric companies to show the steam railroads that they are going to stand back of that system.

MR. DARLINGTON: I am like Mr. Wood; I kept running through in my mind what I had to say to you if called upon, and Mr. Clark has touched upon nearly everything in electric railroading, and I do not think there are any new features that I can talk to you about.

There are a few points about which I take a little different view from Mr. Clark, although, in the main, I agree with what he had said to-night. He has ably summarized the broad facts, yet some of the summaries are capable of different interpretations. For instance, one of his conclusions is that the more closely electric railroad practice approaches a form of what is considered "main line operation," the more successful the electric practice is.

This might be construed in a broad sense to give an incorrect conclusion if we consider the work now being done by main line steam railroads. A great deal of the work now being done by electric railroads is trolley road work, and they are doing it in a better and different way from the steam roads. A great proportion of the trolley road mileage is situated in the Middle West, in Illinois, Indiana, and Ohio, and 90 per cent. of it is parallel to steam roads, and they are doing local business better than the steam roads, and that is one of the sources of profit to electric railroads and one of the reasons for their existence.

Mr. Clark points out one way in which local transportation by electric power is advantageous, when he speaks of what the motor vehicle may be expected to accomplish. He predicts that the time will come when a large part of the local business now done by main line railroads will be done by motor vehicles. This local business electricity is particularly well fitted to do.

One very interesting thing Mr. Clark has said which we are glad to hear is that engineers on railroad construction are taking into consideration the difference between steam and electric motive power. The economy of railroad construction for steam locomotives has been set forth in many books on "Railroad Location," but the great difference in the characteristics of steam and electric motive power makes a large difference in the economy of railroad location for the two kinds of motive power, and Mr. Clark says that six and one-half miles of changed grade, suitable for electric road, in one instance under consideration, will pay for the entire electrification of 160 miles of steam railroad, and that after the road is electrified the operating expenses will

be less than for steam operation. That is one of the most interesting things he has said to-night.

There is one other matter, and that is the economy of diversified use of power from a single central station, supplying electricity for railroad motive power, for industrial uses, for electric lighting, and for all uses of power. There is a large economy in this combination, and it is one of the most important considerations leading to railroad electrification.

The importance of centralization of power generation is shown by the whole history of the electric business, which started with small central stations for lighting and for small motors, and then got to large motors, and then to large power plants in factories, all served from single stations. A great expense and a great source of loss to the originators of this kind of business was from obsolescence, the becoming useless of the plants which had become too small. The central station business has been concentrated in stations of larger size, that are suitable for expansion to meet all needs, because large plants are more economical than small ones, and better transmission systems have been discovered, and made large central plants practical, and consequently, obsolescence to-day is not as serious as it was, because changes in conditions and need for larger powers do not mean that the old plant must be set aside. They simply mean the addition of another generating unit. Central power plants are meeting the demand of railroad motive power much better to-day than a few years ago. Among the different central station plants, Mr. Clark has mentioned Chicago, which is an ideal example of the modern central station.

Wherever large central plants exist there is an opportunity for the steam locomotive to be replaced with electric engines by operating them from these big central stations, and thus getting the same advantages of large centralized units of power that are now being obtained by factories and mills.

Reliability: The fear of unreliability has been one of the bugbears that railroad men have honestly and seriously considered, and it has stood in the way of electrification. With only one generating and transmission system to fall back upon, in case of failure, they say, "Our eggs are all in one basket, and if anything breaks down, we will have to quit."

The truth of the matter is, the fear of unreliability is only a

bugbear. The reliability of an electric locomotive is much greater than steam; it is not affected by cold weather and many other troubles that cause frequent delays to steam trains. So far as the distribution of electric power is concerned, it is so much more reliable than steam engines that failure in transmission is hardly worthy of consideration.

There is one other thing Mr. Clark said which I do not quite agree with; that is, the reason why the railroads of foreign countries have progressed further than we have in the electrification of their roads. This is a subject that I have considered seriously, and I would like to know the answer. It is one of the important things for the railroad officials and for the public to know. Mr. Clark says electrification of railroads is retarded in this country by political agitation. I do not think that is the chief reason we are behind European countries in electrification of railroads. The truth is, our railroads are growing so rapidly in the amount of traffic to be handled, and they are seeking such large returns on their capital, that they can not stop for electrification. It has often been stated, and I believe correctly, that if railroads would be satisfied to make 10 or 12 per cent. on their capital they could spend money freely to electrify their tracks. Now our Legislature is stepping in and our Government is taking a paternal interest in our railroads and saying we are going to prevent your making too much money, and charging unduly high rates for your services, etc., but we are going to allow you to make a fair return on the capital invested; we will regulate that by adjusting rates. That is, I understand, the attitude of the Government. I think that in the end, when this is once fully understood, it will make the railroads feel freer and easier in going into electrification; that they will be allowed to make a fair return on the capital invested, and that will be on a basis of 8 or 10 per cent., more or less, and if that is so, railroads in the United States will be encouraged to go into electrification.

MR. J. B. KLUMPP: We have listened to an exceedingly interesting and instructive paper presented by Mr. Clark. The statistics that he has presented to the Institute and the two societies contain much information that is valuable, and, while we cannot absorb the figures as they were read, they will make a most valuable reference paper, coming from such a prominent authority as the reader.

There seems to have been some discussion as to the factor that has caused the electrification of foreign railroads, more particularly those on the European continent. It seems to me that one of the reasons for this electrification, while undoubtedly due to the heavy traffic and short haul, was influenced by the attitude of the Germans and Italians, in tending to conserve their fuel supply. If we follow for the last ten years the activities of the Germans in certain fields, such as the development of the internal combustion engine and the gas producer, we will appreciate how willing they are to make investments at a much greater cost on first installation, to be able to reduce their operating charges to any extent, and at the same time to produce, for instance, a horsepower hour for an expenditure of half the quantity of fuel in the shape of coal or oil.

When we consider that by the electrification of railroads large central stations may be employed running on a coal consumption of from one to three pounds of coal per horsepower hour, and which can displace the many small units in locomotives, operating anywhere from five to fifteen pounds per horsepower hour, you will appreciate the advantages obtained by such electrification.

The same conservation of energy is obtained by utilizing the current generated from the water powers that have been so completely developed on the continent.

A similar development of water power in the United States should exert an influence toward the electrification of some of our railroads, especially in those sections where the water supply is abundant and the utilization of this power for other purposes is not possible. This might be particularly applicable in some of our mountainous Western districts where the grades are exceedingly heavy and the coal supply scarce.

MR. G. R. HENDERSON: Mr. President, I agree with quite a number of points that Mr. Clark has brought up, particularly when he says that each road is a problem to be worked out by itself; but I cannot agree with him on the ground that it is political intrigue or a battle of systems that prevents the electrification of railroads. I think it is purely and simply a financial proposition, and I do not think it is possible to show an honest return on the electrification of a great many of our main lines of railroads. All the lines that have considered it have argued from the view

point of smoke in their tunnels or congestion of traffic. In other words, if we had had any of the great tunnels electrified there would have been no smoke, and the electrification of the road itself would probably never have been brought up if it had not been for complaints of the smoke nuisance experienced by those who had to go through their tunnels.

The New York, New Haven & Hartford had to electrify part of its road in connection with its traffic with the New York Central. The West Jersey & Seashore Line from Camden to Atlantic City is not troubled with tunnel connections, but there is a great density of traffic.

In Europe, not only the density, but the uniformity of traffic is one of the reasons for electrification being so much more advanced over there than it is here. In Europe there is a constant uniformity of traffic due to density of population, which ensures a steady return on the investment.

The paper by Mr. Wilgus when analyzed showed that if the uniformity of traffic had been less regular, there would have been a loss instead of a gain in the electrification, and that if they were able to operate with only one-half of such a load factor as they were, the interest on the money invested in the power house would be sufficient to overcome all the benefits of the electric traction.

The elevated lines in New York, the Subway Tunnel, and the Chicago elevated have been referred to as illustrating the benefits of electric traction in the reduction of operating expenses, but the uniformity of traffic is applicable there also.

On many lines in the West there are a great many places where there would not be any chance to distribute any surplus electric power, because for one thing, there is not anybody within a hundred miles of many of the places to use the current. Each division would have to be large enough to handle any congestion that might come over the line. Very often some divisions will have only one or two trains a day for four or five days in the week, and then perhaps on two nights stock trains will follow each other at ten or twenty minute intervals, which they have to do in order to deliver the cattle in the Kansas City or Chicago markets in time for the cattle to be sold next day, and if there is any loss in the market price, the railroads have to stand for it.

When you consider that a steam locomotive can be built for in the neighborhood of $15 per horsepower and the power house

and distribution system will cost $100 per horsepower, and when we consider that we cannot move a power house from one point to another as we can a locomotive, the reason why electrification does not progress faster is not hard to find. In the case of the steam railroad, if there is a call for locomotives on any division, we can move them where we need them.

Take, for instance, the Northern Michigan lines, that are entirely closed up in winter, and in the summer time the business is very heavy. In the winter time the locomotives are drawn from those divisions that are closed up, and placed where they can be kept busy.

It has been stated that a great deal of the increase in returns on electrified lines has been due to the increased traffic resulting from the change. Now I do not know that the user would find any satisfaction in receiving or that the shipper would find any satisfaction in shipping a carload of coal over an electric road, any more than over a steam line. It is well known that railroads make nearly all their living from freight traffic. If we consider this, I do not think there is any reason for any argument like that being made. We must have locomotives to haul those cars, and I think the whole thing is simply a question of cost. Personally, although I do not know, I would not be surprised to find that the Pennsylvania Railroad intended to electrify their lines from New York to Washington. The Baltimore and Washington terminals certainly need electrification.

There is another thing to be considered, and that is in the mixing of the steam locomotives and the electric locomotives, the expense of the two together are much greater than where one is used. The changes from electricity to steam make the operation cost greater, by requiring additional crews which make a shorter mileage.

It is not a question of politics or a battle of systems. I think that either the A. C. or the D. C. system will give good service, as has been demonstrated on the New Haven and the New York Central lines. Until the country is populated enough to insure enormous traffic and great uniformity, I doubt whether we will see a great advancement in electrification, and when we consider the main lines of the United States and a general electrification scheme, I am satisfied that there would not be sufficient return to be interesting at all as a financial proposition.

FRANKLIN INSTITUTE

AWARD OF THE ELLIOTT CRESSON MEDAL TO DISTINGUISHED SCIENTISTS.

In its action of awarding the Elliott Cresson Medal to the eminent scientists and technologists whose biographical sketches appear below, the Committee on Science and the Arts has again carried out its principle of according the highest recognition in its power to men who, by their distinguished achievements, have made their names a by-word among their fellow-scientists and, indeed, among the whole human race.

Appointed primarily for the purpose of examining inventions with a view to encouraging their originators, this committee's field of activities has now become extended to the consideration of the life-work of such men who, by their original and fruitful research, have contributed materially to the sum of human knowledge.

While it is true that to perfect a specific invention often involves many years of study and labor on the part of the inventor, it is nevertheless sometimes the case that he receives valuable suggestions from the work of some master mind in the field before him. At the time of the introduction of his invention, in the light of the admiration evoked, this influence may not at once be apparent, and it is only after this emotion has subsided—often after many years—that it becomes revealed.

In this age of world-wide research, therefore, when the difficulty of discriminating between the instigator and propagator of an idea cannot be entirely removed and due recognition accorded, the necessity of meeting it by departing from the original lines and honoring those comparatively few master minds in the fields of science has arisen.

Each of the noted scientists below has been the author of ideas that have led to a number of inventions in use in the arts and industries. Many of these inventions—attributed either to themselves or to their co-workers and collaborators—have already individually received high recognition. At this time, however, it is for that masterful research, the influence of the results of which has already been, and must always be, of inestimable value to their fellow-men, that the Franklin Institute pays its highest tribute to the following distinguished scientists:

ALEXANDER GRAHAM BELL, Sc.D., LL.D.

Prof. Alexander Graham Bell was born at Edinburgh, Scotland, in 1847. He was educated at the Edinburgh High School and University, and trained by his father in the latter's system for restoring speech to deaf-mutes.

In 1870 he removed with his father to Canada, and in 1871 came to Boston as professor of vocal physiology in Boston University, where he taught his father's system with success.

He had long been experimenting on the electrical transmission of sound, had designed and partly constructed a speaking telephone while in Canada, and in 1876 he took out a patent for it. The invention was exhibited at the Centennial Exposition in Philadelphia that year, and foreign scientists applauded it warmly. Professor Bell's discovery of the necessity of a continuous and variable current for the transmission of articulate sounds, in place of the interrupted and uniform electrical impulses which had long been the only means conceived for the purpose, formed the fundamental basis of telephonic science and art. Among his other important inventions are the photophone and the graphophone. His meteorological researches, and especially his investigations of aërial currents, have afforded valuable data for the advancement of the art of aviation.

He has never abandoned his first field, however—that of the instruction and advancement of deaf-mutes—and has investigated and written much on the subject, publishing his papers through the Volta Bureau, which he founded. He has long held the foremost place in this field, and has been president of the American Society to Promote Teaching of Speech of the Deaf.

Professor Bell has received many degrees from American and European universities, among which may be mentioned those of M.D. of Heidelberg University, of LL.D. of Harvard, and of Sc.D. of Oxford, etc. He is an officer of the Legion of Honor of France, a regent of the Smithsonian Institution, and a member of the National Academy of Sciences and of many other leading scientific organizations.

He was the recipient of the Volta Prize from the French Government in 1890, and of the Medal of the London Society of Fine Arts in 1902.

He has been a voluminous contributor to scientific literature, having written many monographs—among others being his "Memoir on the Formation of a Deaf Variety of the Human Race."

SAMUEL WESLEY STRATTON, D.ENG., Sc.D., Director of the National Bureau of Standards, Washington, D. C.

Dr. Stratton was born at Litchfield, Ill., in 1861. He was graduated from the University of Ilinois in 1884. From 1885 to 1892 he was connected with the same institution as instructor in mathematics, later professor, then professor of physics and electrical engineering. In 1892 he went to the University of Chicago as assistant professor of physics, and later became professor, a position which he held until 1901, when he was appointed to his present position of Director of the National Bureau of Standards at Washington.

Among his degrees are those of D.Eng. of Illinois, 1903; D.Sc. of Western University of Pennsylvania, 1903, and D.Sc. of Cambridge, 1908. He was tendered the Cross of Chevalier of the Legion of Honor in 1909.

His activities include a connection with the Naval Militia since 1895. He also served as lieutenant in the Spanish-American War in 1898.

Dr. Stratton was a member of the International Committee on Weights and Measures in 1905, and was United States delegate to the International

Electrical Congress at St. Louis in 1904. His membership in learned societies includes the American Association for the Advancement of Science, the American Institute of Electrical Engineers, American Physical Society, American Philosophical Society, American Society and also International Association for Testing Materials, etc.

In the organization and development of the National Bureau of Standards, Dr. Stratton has rendered a distinguished service to every scientific institution and by his broad-minded policy has made it invaluable to those engaged in the arts and industries of the country.

ALBERT A. MICHELSON, Sc.D., PH.D., LL.D., Professor of Physics, University of Chicago.

Professor Michelson was born at Strelno, Germany, in 1852. He came to this country when a boy; was graduated at the United States Naval Academy in 1873, and was instructor in the same institution from 1875 to 1879.

He took graduate courses in physics in Berlin in 1880, in Heidelberg in 1881, and in Paris in 1882. In the meantime he had resigned from the navy to become professor of physics at the Case School of Applied Science, Cleveland, Ohio. From 1889 to 1892 he was professor of physics at Clark University, and since that date has been head of the Department of Physics in the University of Chicago.

His degrees include those of honorary Ph.D. of Western Reserve, 1886; Sc.D. of Cambridge, 1899; LL.D. of Yale, 1901, and of Pennsylvania, 1906; honorary Ph.D. of Leipzig, 1909.

Professor Michelson has earned a world-wide reputation for his researches in light and for the Michelson and Morley experiment devised for examining the effects resulting from the relative motion of ether and matter. His early experiments in light gave new figures for the velocity of light in vacuo. His inferential refractometer made it possible to use wave-lengths of light as a measuring unit; this discovery was put to concrete use by his measuring a metre in terms of cadmium-light wave-length, enabling the original standards to be replaced at any time. This same instrument not only determines wave-lengths of red, green, and blue cadmium light, but separates lines less than one-thousandth metre apart, and hence is a very delicate dividing machine.

Another of Professor Michelson's important inventions was the echelon grating. This is used in spectroscopes of the highest resolving power, and is especially valuable in the study of magneto-optics, particularly the Zeeman effect.

His researches have brought to him many distinguished honors. In 1889 he was awarded the Rumford Medal; in 1900 the Grand Prix at the Paris Exposition; in 1907 the Copley Medal of the Royal Society, and in the same year he received the Nobel Prize for Physics from the Swedish Academy of Sciences.

Professor Michelson was a member of the International Commission on Weights and Measures in 1897. He is connected with many important scientific societies, among them being the National Academy of Sciences, the

American Physical Society, American Philosophical Society, and several foreign institutions, including the Royal Society, etc. He was president of the American Physical Society in 1900.

He is a contributor to the *Philosophical Magazine*, to *Nature*, and to the *American Journal of Science*, etc., chiefly on researches in light.

ALFRED NOBLE, C.E., LL.D., Consulting Civil Engineer.

Mr. Alfred Noble was born at Livonia, Mich., in 1844, and was graduated from the University of Michigan in 1870. After his graduation he was for some months engaged on harbor surveys on Lakes Michigan and Huron, and was then placed in charge of the improvement of the St. Mary's Falls Canal—a position which he held for twelve years.

In 1892 Mr. Noble resigned from the government service and, after serving some months as engineer of construction of the Red River Bridge at Shreveport, La., he was appointed general assistant engineer of the Northern Pacific Railroad, in which position he continued for three years.

From 1886 to 1894 Mr. Noble had special charge of the construction of several important bridges in various sections, among them being the Bellefontaine and the Leavenworth bridges over the Mississippi.

In 1895 he was appointed a civilian member of the first Nicaragua Canal Commission. The report of this commission led to the abandonment of the Maritime Canal Company's route. Mr. Noble was also a prominent member of the Isthmian Canal Commission of 1899. He also rendered important service as a member of the United States Deep Waterway Commission in 1897.

Following his activities on these commissions, Mr. Noble was engaged in private practice in a number of important works. From January, 1902, to 1910, he was chief engineer of the East River Division of the Pennsylvania Tunnel and Terminal Railroad during the period of the construction of the four tunnels across the East River and of the Terminal Station. In 1905 Mr. Noble was appointed by President Roosevelt a member of the International Board of Consulting Engineers on the Panama Canal. Since May, 1909, he has been in general consulting practice with the firm of Noble & Woodard. He now acts as consulting engineer to the Board of Water Supply of the City of New York.

His connection with learned societies has included the presidency of the American Society of Civil Engineers and of the Western Society of Engineers; it also embraces membership of the Institution of Civil Engineers of Great Britain, etc. In 1895 Mr. Noble received the honorary degree of LL.D. from Michigan University.

In 1910 he was presented with a Fritz Medal for notable achievements in civil engineering.

ELIHU THOMSON, Sc.D., PH.D.

Dr. Elihu Thomson was born in Manchester, England, in 1853. At the age of five he came to this country, was educated in the public schools of Philadelphia, and was professor of chemistry and mechanics at the Central High School here, from 1870 to 1880.

After a visit to the Paris Exposition in 1878 he became interested in the subject of lighting by electricity, and his experiments, carried on with the aid of E. J. Houston, resulted in patents secured in 1878 and 1879. The following year he became electrician to the American Electric Company, afterwards known as the Thomson-Houston Electric Company. This, by consolidation with the Edison Company in 1892, became the present General Electric Company.

Among his numerous patented inventions are the three-coil armature for dynamos and motors; the induction coil system of distribution; the induction motor; the electric-welding process; the electric meter for direct and alternating currents, and many others in electric lighting, power, etc.

Since 1892 he has retained his connection as consulting engineer to the General Electric Company.

Professor Thomson has been accorded many honors for his electrical work. He was decorated by the French Government in 1889, and was awarded the Grand Prix in Paris in that year and in 1900. In 1902 he was the recipient of the Rumford Medal, and in 1904 of the Grand Prize at St. Louis.

His connection with scientific societies includes membership of the National Academy of Sciences, of the Institution of Electrical Engineers, and of the Institution of Civil Engineers of Great Britain, etc. He was elected president of the American Institute of Electrical Engineers in 1889.

Among the most notable of his papers prepared for scientific societies are those on "Electric Welding," read before the Franklin Institute in 1887, and on "Novel Phenomena of Alternating Currents," prepared for the American Institute of Electrical Engineers in 1887.

EDWARD WILLIAMS MORLEY, Sc.D., PH.D., LL.D., Emeritus Professor of Chemistry, Western Reserve University.

Dr. Edward Williams Morley was born at Newark, N. J., in 1838. He was graduated from Williams College, Williamstown, Mass., in 1860. He was elected to the chair of chemistry in Western Reserve College, Hudson, Ohio (later Adelbert College, Cleveland, Ohio), in 1869, and retained the office until 1906, when he became emeritus professor. He was also professor of chemistry at Cleveland Medical College, 1873–8.

His degrees include those of LL.D. of Williams, 1901, Western Reserve, 1891, and Lafayette, 1907; honorary, Ph.D. of Wooster, and Sc.D. of Yale, 1909.

Professor Morley is a member of several leading scientific societies, among them being the American Association for the Advancement of Science, of which he was president in 1895; the American Chemical Society, of which he was president in 1899; the National Academy of Sciences, American Chemical Society, and foreign societies, including the Royal Institution, etc.

By a series of admirable experiments and measurements he has determined with hitherto unattained precision some of the fundamental magnitudes in chemical science. These include the atomic weight of oxygen, the gravimetric synthesis of water, the density ratio of oxygen to hydrogen, and the redetermination of the composition of water by volume.

Professor Morley has also made accurate determinations of the vapor

density of mercury between 0° and 100°, and has repeated the Michelson-Morley experiment in view of the Lorentz-Fitzgerald suggestion that the form of bodies may depend on translation through the luminiferous ether.

Among his papers is "The Atomic Weight of Oxygen," which appeared in the Smithsonian contributions to *Knowledge*, 1895.

JOHANN FRIEDRICH WILHELM ADOLPH VON BAEYER, PH.D., F.M.R.S.

Dr. Baeyer was born in Berlin in 1835. He studied chemistry under R. W. Bunsen and F. A. Kekulé, and in 1858 took his degree as Ph.D. at Berlin, becoming privadocent a few years afterwards and assistant professor in 1866. Five years later he was appointed professor of chemistry at Strassburg, and in 1873 he migrated in the same capacity to Munich, where he now resides.

He has devoted himself mainly to investigations in organic chemistry, and in particular to synthetical studies by the aid of "condensation" reaction. The experimental researches of himself and pupils extend over a vast range of organic compounds, and it may be said of them that they have greatly augmented, and in some cases completed, our knowledge of certain most important groups of the carbon compounds; notably they have elucidated the nature and composition of indigo, have led to the discovery of the phthaleins, with eosin, and to the synthetic production of many dyestuffs.

Among the most important groups successfully studied by Professor Baeyer may be mentioned the cacodyl compounds; uric acid and its derivatives; the condensation products resulting from the action of aldehydes on hydrocarbons and phenols; benzene, the terpenes, and the ptomaines, etc. In his laboratory Turkey-red or alizarin was first made from anthracene, and Fischer discovered benzaldehyde-green.

To celebrate his seventieth birthday, his scientific papers were collected and published under the title of "Gesammelte Werke," Brunswick, 1905. These papers included his writings for the *Berichte Deutschen Chemischen Gesellshaft*, Berlin, and Liebig's *Annalen der Chemie*, etc.

SIR WILLIAM CROOKES, D.Sc., LL.D., F.R.S., O.M., Foreign Secretary to the Royal Society.

Sir William Crookes was born in London in 1832, and studied chemistry under von Hoffman, whose assistant he became in 1851. Three years later he accepted a position in the meteorological department of the Radcliffe Observatory, Oxford, and in 1855 was appointed professor of chemistry at the Training College, Chester.

In 1861, while engaged in the spectroscopic examination of the residue left in the purification of crude selenium, he succeeded in isolating thallium, and during the next twelve years he carried out a minute investigation of this metal and its properties.

While engaged in the determination of its atomic weight, discouraging irregularities led him to make his weighings in a partial vacuum. Sometimes

he found the metal to be heavier when cold than when in a heated condition, and this led to his principle of "repulsion resulting from radiation." In 1875 he invented his radiometer for illustrating such phenomena. He was thus brought into touch with the dynamical theory of gases and with experimental work in high vacua, and so came to his famous researches on the electric discharge in gases. These in turn led him to formulate his theory on the "Fourth State of Matter."

In 1881 his paper on radiant matter spectroscopy appeared, and in 1883 he began an inquiry into the nature and constitution of the rare earths.

In the course of this work he succeeded, by means of fractional crystallization, in resolving yttrium into portions that gave different spectra, and, believing this to be due to a disruption of the yttrium atoms, he formulated his hypothesis that the chemical elements are products of an evolution from a primordial or protyle matter.

Sir William is one of the foremost authorities on precious stones, especially on the diamond, minute specimens of which he has succeeded in making artificially.

Upon the discovery of radium he was early in the field in taking up the study of its properties. In 1900 he first effected the separation from uranium, by two distinct chemical methods, of the one direct transformation product called uranium X.

He discovered, in 1903, that the alpha rays from radium produce phosphorescence on a target of crystalline zinc sulphide. This wonderful phenomenon was popularized in his spinthariscope.

Sir William is the author of various works on chemistry and chemical technology, including "Select Methods of Chemical Analysis" and several papers on dyeing, etc. He has also devoted some time to the investigation of psychic phenomena. He is proprietor and editor of the *Chemical News*.

He is a member or corresponding member of scientific societies in his own country and abroad. At one time or other he has occupied the chair of many of the leading learned societies of Great Britain. The Royal Society awarded him the Royal Medal in 1875, the Davy Medal in 1888, and the Copley Medal in 1904. The French Academie des Sciences similarly recognized his work in 1880, and the Society of Arts with the Albert Medal in 1899. He was knighted in 1897 by Queen Victoria.

SIR HENRY ENFIELD ROSCOE, PH.D., LL.D., D.C.L., F.R.S., Emeritus Professor of Owens College, Victoria University.

Sir Henry Enfield Roscoe was born in London in 1833. After studying at Liverpool High School and University College, London, he went to Heidelberg to work under R. W. Bunsen. In 1857 he was appointed to the chair of chemistry at Owens College, Manchester, where he remained for thirty years. From 1885 to 1895 he was member of Parliament for the South Division of Manchester, and from 1896 to 1902 vice-chancellor of London University.

Sir Henry has served on several important royal commissions appointed

to consider educational questions; notable among these were the Commission on Technical Education, on Scottish Universities, and on Secondary Education.

His degrees include those of Ph.D. and of honorary M.D. of Heidelberg, the former in 1853 and the latter in 1887. He was knighted in 1884.

Sir Henry's scientific work includes a memorable series of "Researches on the Chemical Action of Light," carried out with Bunsen between 1855 and 1862, in which were laid the foundations of comparative photo-chemistry.

In 1867 he began an elaborate investigation of vanadium and its compounds, and devised a process for preparing it pure in the metallic state. He performed extended and fruitful work on tungsten and uranium, and made numerous interesting applications of spectrum analysis to the solution of scientific and industrial problems. He was also author of researches on niobium, perchloric acid, and the solubility of ammonia, etc.

His publications include, beside several elementary works on chemistry which have been circulated universally, "Lectures on Spectrum Analysis," 1869; "A Treatise on Chemistry," 1877; "A New View of Dalton's Atomic Theory," with Dr. A. Harden, 1896, and a charming autobiography, "Life and Experience of Sir Henry Roscoe." The "Treatise on Chemistry," written in collaboration with Carl Schorlemmer, his private assistant, has for a generation past been the standard work on the subject.

He is a member of many leading scientific societies, including the Chemical Society and the British Association, of which he was president in 1887, and is an officer of the Legion of Honor of France.

Proceedings of the Stated Meeting held Wednesday, May 15, 1912.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 15, 1912.

MR. JAMES MAPES DODGE *in the Chair.*

The following proposed amendment to the By-Laws was presented for final action:

> Article XIII, Section 1, to be amended by striking out "and" in 3d line, and adding "June" before "July" in 3d line; and adding "and September" after "August" in 4th line, so that by-law, after amendment, will read as follows, the new matter being in italics:

ARTICLE XIII.

> SECTION 1.—"The Institute shall hold stated meetings on the third Wednesday of each month, except in *June*, July, August, *and September*. That on the third Wednesday in January of each year shall be the annual meeting."

On motion, duly seconded, the amendment was adopted.

Dr. Alexander Graham Bell was then introduced by Dr. Harry F. Keller to the Chairman, who presented him with the Institute's Elliott Cresson

Gold Medal and Diploma in recognition of his solution of the problem of the electrical transmission of articulate speech.

The following eminent scientists were also presented by Dr. Keller and received the Cresson award:

Dr. Edward Williams Morley, in recognition of his important contributions to chemical science, and particularly of his accurate determinations of fundamental magnitudes.

Professor Elihu Thomson, in recognition of his leading and distinguished work in the industrial applications of electricity.

Dr. Samuel Wesley Stratton, in recognition of his distinguished and directive work in physical science and metrology, and its application in the arts and industries.

The Chairman stated that the recipients of the medals were four of the nine scientists and technologists to whom the awards were made.

The remaining awards were made as follows:

To Dr. Albert A. Michelson, in recognition of his original and fruitful investigations in the field of physical optics.

To Dr. Alfred Noble, in recognition of his distinguished achievements in the field of civil engineering.

To Dr. Johann F. von Baeyer, in recognition of the many important results of his extended research in organic chemistry and of his discovery of synthetic processes of great industrial value.

To Sir William Crookes, in recognition of his important discoveries in inorganic and analytical chemistry and of his pioneer work on the discharge of electricity through gases.

To Sir Henry Enfield Roscoe, in recognition of his extended and important researches in the domains of inorganic, physical, and industrial chemistry..

Dr. Keller read letters of acknowledgment from the latter two recipients.

A biographical note and statement of the work of each of the above appears elsewhere in this issue.

In introducing the medallists, Dr. Keller said:

"*Mr. President:* It is a curious fact that it often happens that a man who is but little known to an audience is called upon to introduce men who are known to everyone present, but never have I been so impressed with this anomaly as on this auspicious occasion, when to me, as a member of the Committee of Awards, has been assigned this extremely gratifying duty and rare privilege to introduce to you, and, through you, to this brilliant assembly, the famous scientists, investigators, and inventors who have come hither to accept from your hands the highest award which this venerable Institute, named in honor of the greatest American scientist, has the power to bestow.

"The first on the list is a name that is illustrious the world over; it has come to be a household word in every land; in fact, it would be difficult to find another scientist whose name has become so universally popular. It would seem presumptuous on my part if I attempted to characterize the great work which this man has done; you all know it; his life's work has touched many human interests, but most of all it has been concerned with

one of the foremost interests, that of 'human speech.' Born in Edinburgh, Scotland, Dr. Bell came to Canada at the age of twenty-three, and in the following year to this country, to Boston, where he taught his father's system of imparting the faculty of speech to deaf-mutes. He has never abandoned this field, and, I believe, is easily the first investigator and authority in it; but he was to make even greater achievements in another field—that of the electrical transmission of articulate sound. His experiments in that direction began in 1871, but it was not until 1876, when the Centennial of the Independence of the United States was being celebrated by an International Exposition in this city, that he first made the world acquainted with that most wonderful invention of his, the first successful speaking telephone. I need not explain here the principle upon which this great invention is based. The apparatus exhibited here in 1876 has been modified and improved in many ways, but fundamentally its principle has remained the same.

"Our medallist of this famous name has made many other achievements and great inventions, among which may be mentioned the graphophone and the photophone; he has also studied the atmosphere and aërial currents, and has thus materially advanced the new art of aviation."

In introducing Dr. Morley: "Among the various activities of The Franklin Institute during the past eighty-seven years chemistry has taken a prominent and a noble part. Our Institute has numbered among its members a great many of the distinguished chemists of the country. This old hall has been the scene of innumerable lectures and communications on the subject, both pure and applied. Our audiences have witnessed hundreds of experimental demonstrations of chemical discoveries and inventions. Our Committee on Science and the Arts has recognized the great achievements of chemists, both here and abroad, by the award of medals and in other ways. I feel sure that the Elliott-Cresson Medal—the highest award this Institute has to give—has never been bestowed upon a worthier representative of chemistry in America than it will be to-night. The man whom we intend to honor has not written a great many papers nor voluminous books, but the results of his investigations are of fundamental importance. His researches are of the highest rank, and are recognized everywhere as models of scientific acumen and experimental skill. Among the main results of these investigations are the exact determination of the atomic weight of oxygen, of the densities of oxygen and hydrogen, and of the exact ratio between these two elements, as well as a complete synthesis of water. Many great chemists in Europe and this country had already bent their energies to determine these constants, but none, so far as I know, has equalled his work in accuracy. In recent years American chemical research has taken rank with that of the older countries of Europe; but I believe I will not be contradicted if I say that no single piece of experimental chemical work has reflected greater credit on American chemistry than has this classic on the atomic weight of oxygen and the composition of water. Though by no means the only research work he has done, it is, I think, in itself quite sufficient to secure for him the Elliott-Cresson Medal."

In introducing Dr. Stratton: "From the oldest times the subject of

'Weight and Measures'—that is, of the comparison of unknown quantities with known magnitude or units—has been one of vital and universal concern. It is only in modern times, however, that this subject has been developed along scientific lines—that the truly chaotic condition in which weights and measures used to be has been transformed into a science. The development of this science of metrology has been somewhat slow and gradual. One of the steps toward securing an ideal system of weights and measures (one of the greatest steps, perhaps) was the creation in France, at the time of the Revolution, of the Metric System, which was designed to replace the old and incongruous weights and measures then in use in different parts of that country. Since that time the metric system has been introduced into most civilized countries and has been adopted universally by men of science. This international use of the metric system has led to the establishment of the International Bureau of Standards and of Weights and Measures in Paris, and from this great institution have descended a number of national bureaus of standards in the different countries, even where the metric system is not used, or, shall I say, 'not yet used.'

"The Bureau of Weights and Measures in Washington is one of the most active and most successful of its kind. During the ten years it has been in existence it has done the most splendid work, conferring the greatest benefits upon both science and the industries. The work of that great institution is not simply the construction and comparison of standards; it is far more than that. Its highly-trained scientific staff is engaged in the solution of scientific as well as industrial problems of the highest importance. The organization, direction, and the success of that great laboratory is largely due to the efforts of one man, to him whom we have with us this evening, the distinguished mathematician, physicist, and electrical engineer."

In introducing Dr. Thomson: "It is with a peculiar sentiment of pleasure and satisfaction that I present to you the fourth medallist on our list, for he is one of my honored predecessors in the chair of chemistry at the Central High School, and a man who has left a deep and lasting impression on the scientific teaching and investigation of that school and on the whole scientific world.

"Forty years ago science, natural as well as physical, was taught at the High School, as it was in all similar schools at that time, by lectures and recitations. Good work, no doubt, was done, but an important element of instruction was lacking. In 1870 there was appointed in the Central High School a young and enthusiastic man, first as instructor in chemistry, and later in chemistry and mechanics. The laboratory he found there was only a store-room for chemicals and apparatus, and now and then, perhaps, one of the professors would venture into this basement room and make a demonstration before a small class. The young instructor fitted up that laboratory and introduced regular exercises in chemistry and laboratory work. I believe it was the first work of this kind done in any high school in the country—I may be mistaken about that, but it certainly was one of the first instances. But he did far more than that: indefatigably he worked in that laboratory himself. A born investigator, he constructed novel forms of apparatus, devised new experiments, brought to light new facts of science,

and invented practical applications of scientific discoveries. At the same time he was connected with this Franklin Institute. He became interested in electrical work in connection with our Committee on Science and the Arts, and, I believe, delivered courses of lectures on electricity in the Evening School of this Institute. Like Faraday, he started as a chemist, and gave more and more time to physical investigation, until finally he became an electrician of the first rank. Then the school could hold him no longer. He abandoned teaching in 1880 and since that time he has made almost innumerable valuable inventions. The are too many of them even to mention the more important ones. It is the record of this magnificent work that has made him famous the world over and in recognition of which the Elliott Cresson Medal is to be bestowed upon him."

After the presentations, Professor Morley gave a brief address on "Fundamental Chemical Constants." Dr. Morley spoke of the bearing of the determination of such constants as atomic weights on our knowledge of the nature of matter. He reviewed his work on the atomic weights of oxygen and other elements and on the synthesis of water.

Prof. Elihu Thomson outlined "Recent Developments in the Electrical Art." By giving a brief summary of the present-day applications of electricity in the arts and industries, he demonstrated the fulfilment of his early prophecy on the future of the art. He spoke of the growing tendency to generate one kind of electric current only, rectifying and transforming this locally for use for all purposes. In the course of his remarks Dr. Thomson gave interesting reminiscences of his early work and experiments carried out at the Franklin Institute.

Dr. Stratton presented a short paper on "Metrology in Relation to Industrial Progress," in which he reviewed the growth of metrology with the advance of civilization. He referred to the formation and present work of the National Bureau of Standards, and spoke of the influence of the bureau on the industrial and commercial progress of the country, in supplying standards for all purposes and in encouraging the establishment of research laboratories by industrial concerns.

Adjourned.

R. B. OWENS,
Secretary.

CORRESPONDENCE.

From Sir William Crookes, O.M., F.R.S.,

7 KENSINGTON PARK GARDENS,
LONDON, W.,
March 11, 1912.

R. B. OWENS, ESQ., *Secretary,*
The Franklin Institute,
Philadelphia, Pa., U. S. A.

DEAR SIR:

I am deeply sensible of the honor paid to me by the Franklin Institute in awarding the Elliott Cresson Gold Medal for my scientific work; I return

my warmest thanks for a recognition, precious as it is wholly unexpected. And I thank my Philadelphia friends for the flattering terms of the announcement. It is an especial pleasure to find myself associated with so distinguished a band of scientific researchers, with most of whom I happily have the pleasure and privilege of being personally acquainted.

Following the desire of my heart, I have been able to devote a considerable portion of the last fifty years to the irresistibly fascinating pursuit of original scientific research. Your generous appreciation of my work will stimulate me to break down more barriers, to penetrate deeper into those baffling regions where in all departments of science illimitable domains await exploration.

Believe me to remain,

Very truly yours,

[Signed] WILLIAM CROOKES.

WOODCOTE LODGE, WEST HORSLEY,
LEATHERHEAD, LONDON, S. W.,
March 15, 1912.

DEAR SIR:

I have received, through the kindness of my friend, Mr. James Bryce, British Ambassador at Washington, your kind letter of February 20th, in which you inform me that the Franklin Institute have done me the honor to award to me its Elliott Cresson Medal.

I beg that you will express to your Committee of Science and the Arts my sense of the great honor which they have done me, and offer to them my most grateful thanks.

I wish to add that I feel this the more keenly because I find my name associated with men of the highest distinction, many of whom I have the privilege of claiming as personal friends.

I am, dear sir,

Yours sincerely,

[Signed] HENRY E. ROSCOE.

R. B. OWENS, ESQ.,
Secretary, Franklin Institute,
Philadelphia.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 1, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 1, 1912.

DR. GEO. A. HOADLEY *in the Chair.*

The following reports were presented for first reading:

No. 2507.—Squier's Multiplex Telephony.

No. 2517.—Dietz's Multi-Speed Shutter.

Final action:

No. 2383.—Downes's Asbestos-Covered Magnet-Wire. Scott Award. Adopted.

No. 2477.—Granbery's Stadia Rod. Longstreth Medal. Adopted.

No. 2508.—Turner's Air-Brake Improvements. Cresson Medal. Adopted.

No. 2514.—Kennicott Water Weigher. Scott Award. Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section of Physics and Chemistry, the Philadelphia Branch of the American Pharmaceutical Association, and the Scientific Section of the Philadelphia Branch of the American Pharmaceutical Association was held in the Hall of the Institute on Thursday, April 25, 1912, at 8 P.M. The presiding officers were Dr. Robert H. Bradbury, president of the Sections of Physics and Chemistry of the Franklin Institute, and Dr. F. E. Stewart, president of the Philadelphia Branch of the American Pharmaceutical Association. One hundred members and visitors were present. The minutes of the previous meeting were approved as published.

Dr. William J. Gies, professor of biological chemistry in Columbia University, delivered a lecture on "Chemical Defences of the Organism against Disease."

John Morris Weiss, B.S., B.A., of New York City, read a paper by J. T. Ainslie Walker, F.R.S.M., F.C.S., and himself, entitled "Note on the Rideal-Walker Phenol Control: A Possible Discordant Factor in the Standardization of Disinfectants."

Both communications were discussed at length, and a vote of thanks was given to the lecturers. Dr. Stewart, on behalf of the members of the American Pharmaceutical Association, expressed their pleasure at having participated in the joint meeting. Adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

Election to Membership.

RESIDENT.

MR. WM. R. WARNER, JR., Duffryn Mawr, Pa.

Changes of Address.

MR. RICHARD L. BINDER, 931 North Eighth Street, Philadelphia, Pa.

MR. THOS. L. BURTON, 318 Westinghouse Building, Pittsburgh, Pa.

MR. ARTHUR D. EDGERTON, Agness, Oregon.

MR. F. E. HAYES, JR., care of Ballard & Ballard, 912 East Broadway, Louisville, Ky.

MR. W. R. HUTTINGER, Grove City, Pa.
MR. ERNEST JOHANSEN, in care of Mr. C. P. Dexter, Battle Creek, Mich., R. F. D. No. 1.
MR. FRANK KLEPETKO, 80 Maiden Lane, New York City.
MR. W. G. MATTHEWS, Box 1492, Jacksonville, Fla.
MR. RALPH D. MERSHON, 80 Maiden Lane, 19 Cedar Street, New York City.
MR. ALBERT L. WEBSTER, Room 1930, 80 Maiden Lane, New York City.
DR. HARVEY W. WILEY, Room 1120, Woodward Building, Washington, D. C.
MR. I. B. WILSON, JR., I.E., Construction Gas, Electric Light and Power Company, Lexington and Liberty Streets, Baltimore, Md.

NECROLOGY.

Mr. A. J. Lamborn, Real Estate Trust Building, Philadelphia, Pa.
Dr. O. Brunel-Haccius, Geneva, Switzerland.
Mr. W. C. Wetherill, 703 Symes Building, Denver, Colo.

LIBRARY NOTES.

Purchases.

BLÜCHER, H.—Modern Industrial Chemistry, 1911.
STEINMETZ, C. P.—Elementary Lectures on Electric Discharges, 1911.
STROMEYER, C. E.—Marine Boiler Management and Construction, 1907.
KENT, WILLIAM.—Steam-boiler Economy, 1910.
Trustees Gas Educational Fund.—Catechism of Central Station Gas Engineering [c1909].
CLASSEN, A.—Theorie und Praxis der Massanalyse, 1912.
LAKE, E. F.—Composition and Heat Treatment of Steel, 1911.
OSTWALD, W.—Grosse Männer, 1910.
Railway Signal Dictionary, 1911.
GARRETT, A. E.—The Advance of Photography, 1911.
LEHMANN, O.—Die neue Welt der flüssigen Kristalle, 1911.
CARPENTER, R. C. and H. DIEDERICHS.—Experimental Engineering, 1912.
FOULER, G. L.—Forney's Catechism of the Locomotive, 1911.
MACFARREN, H. W.—Text-book of Cyanide Practice, 1912.
FULTON, C. H.—Principles of Metallurgy, 1910.
CAMPBELL, H. H.—The Manufacture and Properties of Iron and Steel, 1907.
BOTTLER, M.—German Varnish-making, 1912.
INGRAM, E. L.—Geodetic Surveying, 1911.
KIRK, E.—A Practical Treatise on Foundry Irons, 1911.
BOHLE, H. and D. ROBERTSON.—Transformers, 1911.
RICHARDS, J. W.—Metallurgical Calculations, parts 2 and 3, 1910 and 1908.
PARR, G. D. A.—Electrical Engineering Testing, 1907.
ECKEL, E. C.—Building Stones and Clays, 1912.
BARR, W. M.—Pumping Machinery, 1909.

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New York Education Department, State Library Report for 1909 and 1910. Albany, 1911. (From the Department.)

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U. S. National Museum Report for 1911. Washington, 1912. (From the Smithsonian Institution.)

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Institution of Civil Engineers, Minutes of the Proceedings, vol. 184, 1911–12. London, 1912. (From the Institution.)

Philadelphia City Trusts, Forty-second Annual Report of the Board of Directors, 1911. Philadelphia, 1912. (From the Board.)

U. S. Department of Commerce and Labor, The Effects of Topography and Isoctatic Compensation upon the Intensity of Gravity. Washington, 1912. (From the Department.)

Atlantic Deeper Waterways Association, Report of the Proceedings, 1911. Philadelphia, 1911. (From the Association.)

Canada, Department of Trade and Commerce, Report Part 7, 1911, Trade of Foreign Countries and Treaties and Conventions. Ottawa, 1912. (From the Department.)

Stevens, Horace J., The Cooper Handbook, vol. 10, 1910–1911. Houghton, 1911. (From the author.)

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Maryland Geological Survey, Report Vol. 9, 1911, Geology and Paleontology; Report Vol. 4, County Resources; Report Vol. 6. Baltimore, 1912. (From the State Geologist.)

Japan Imperial Investigation Committee on Earthquakes, vol. 6. No. 1. Tokyo, 1912. (From the Committee.)

U. S. Department of Commerce and Labor, Commerce and Navigation of the United States, 1911. Washington, 1911. (From the Department.)

Pennsylvania—Commissioner of Banking, Report for 1910, part 2, Building and Loan Associations; Department of Mines, Report 1910, part 1, Anthracite, part 2, Bituminous; Smull's Legislative Handbook, 1911; Department of Fisheries, Report for 1911; Secretary of Internal Affairs, Report for 1910, part 1, Land Office, Boundary Lines; part 2, 1910, Assessments, Taxes; part 3, 1910, Industrial Statistics; part 4, 1910–1911, Railroads, Canals, Telegraphs, and Telephones. Harrisburg, 1910–1912. (From the State Library.)

U. S. Department of the Interior, Bureau of Education, Report of the Commissioner, vol. 1, 1911. Washington, 1912. (From the Department.)

Hamilton Association, Journal and Proceedings, 1907–1908. Hamilton, 1908. (From the Association.)

New York City, Borough of Manhattan, Investigation and Report upon Gas Pressure Conditions. New York, n. d. (From the Public Service Commission.)

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American Gas Institute, Proceedings, vol. 6. Easton, Pa., 1912. (From the Institute.)

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THE CENTENARY OF THE INTRODUCTION OF GAS AS AN ILLUMINANT.

BY

WALTON FORSTALL,

Assistant Engineer of Distribution, Philadelphia Gas Works.

ON April 18th and 19th the Centenary of the Introduction of Gas as an Illuminant was celebrated in the Hall of the Institute. Three societies joined with the Institute in this event, *viz.*, the American Philosophical Society, the American Chemical Society, and the American Gas Institute. The initiative was given by a paper on "The Present Status of the Gas Industry and its Outlook," read by Dr. Charles E. Munroe, of the George Washington University, at the December, 1911, meeting of the American Chemical Society. A

committee was appointed by this meeting to confer with the American Gas Institute and other interested societies. The American Philosophical Society welcomed the idea and was willing to devote one session to this purpose at its April meeting. The Franklin Institute, for reasons to be more fully explained, was glad to participate, and offered its Hall for any or all of the sessions. In the last form this invitation was finally accepted, because it was decided that the meeting-room of the Philosophical Society would be inadequate in size. The American Gas Institute, as the national representative of the gas profession, appreciated its responsibility in the matter and, through its Technical Committee, secured the lecturers and cared for the many details involved.

It was indeed fitting that the Franklin Institute should not only participate but act as host on this occasion, for both now and its earliest days its relation to the gas industry has been most intimate. Samuel Vaughan Merrick is the link in the past. He is considered as one of the two founders of the Institute. He was on the Board of Managers from 1824 to 1863, and was president from 1841 to 1853. He designed and constructed in 1835–6, the original Philadelphia Gas Works, located at Market Street and the Schuylkill River. To his success in this work eloquent testimony was borne, at the celebration, by a silver pitcher loaned by J. Vaughan Merrick, on which was inscribed " Presented to Samuel V. Merrick, Engineer, by the Stockholders, in testimony of their admiration of his skill in designing and his success in the construction of the Philadelphia Gas Works, January 22nd, 1838." Walton Clark, president of the Institute, is a past president of the American Gas Institute and its predecessor, the American Gas Light Association, and as second vice-president of The United Gas Improvement Company is the engineering head of the largest owner of gas properties in this country.

The programme of the celebration is inserted here for purposes of record.

PROGRAMME.

THURSDAY, APRIL 18TH, 1912,
8.00 P.M.

By-Products in Gas Manufacture.

By CHARLES E. MUNROE, PH.D., Washington, D. C.,
Professor of Chemistry and Dean of the School of Graduate Studies, The George Washington University.

FRIDAY, APRIL 19TH, 1912,
10.00 A.M.

The Commercial and Financial Aspects of the Gas Industry.

By HON. GEORGE B. CORTELYOU, New York.
President of the Consolidated Gas Company.

11.00 A.M.

The Technique of Gas Manufacture.

By ALFRED E. FORSTALL, M.E., New York.

Secretary, Trustees Gas Educational Fund of the American Gas Institute, and Past Secretary, American Gas Light Association.

2.00 P.M.

Gas as an Illuminant.

By VAN RENSSELAER LANSINGH, B.S., New York.

President of the Illuminating Engineering Society.

3.00 P.M.

The Use of Gas for Heat and Power; The Testing of Gas.

By EDWARD B. ROSA, PH.D., Washington, D. C.

Chief Physicist, National Bureau of Standards.

The lectures themselves are to be found in this and succeeding issues of the JOURNAL. The Thursday evening session was called to order by Dr. W. W. Keen, president of the American Philosophical Society, with a few remarks on the great part played by gas in adding to the sum of human welfare. The Friday morning session was opened by Dr. A. D. Little, president of the American Chemical Society. The afternoon session had as chairman James Mapes Dodge, vice-president of the Institute. It should be stated here that Walton Clark, president of the Franklin Institute, and Ira C. Copley, president of the American Gas Institute, were unable to be present, the former because of absence from the country, the latter because of sickness.

There were two events on Friday, not shown on the programme. The first was after Mr. Cortelyou's lecture, when the Chairman requested those in the audience to rise who had been engaged in the gas business thirty years or more. Seventeen responded, and among them was L. H. Davis, in his ninetieth year, who built a gas works at Troy, N. Y., in 1848, and a number of others in rapid succession immediately thereafter. The second event was a luncheon to the audience between the morning and afternoon sessions. This was tendered by The United Gas Improvement Company, and its president, Mr. Samuel T. Bodine, welcomed the guests.

The attendance at all the sessions was excellent, the Hall, with a seating capacity of three hundred, being almost filled. The greatest interest was shown not only in the lectures but also in the Loan Exhibition mentioned on the programme. A list of the articles on exhibition is appended as a part of this account. The exhibition was held in the first-floor room north of the hallway, the room being kindly loaned for the purpose by its present occupants, the Committee on Science and the Arts. Four excellent photographs taken of the exhibition are now part of the records of the Institute. There was also in the wall of the stairway leading to the second floor an exhibit of most of the modern forms of gas burners.

It is to be regretted that every member of the Institute was not able to be

present on this thoroughly enjoyable occasion, the latest of many historic celebrations held in the venerable Hall.

In closing, an opportunity is here taken to thank, in the name of the Institute, all who contributed to the success of the Centenary.

LIST OF EXHIBITS, TEMPORARY LOAN EXHIBITION.

Loaned by the United Gas Improvement Company

Original model of Lowe water gas apparatus from which the patent was made.

Old gas meter.

Pentane lamp: English photometric standard certified by the Board of Trade for testing purposes in London in the 70's.

Hefner lamp, German photometric standard.

Carcel lamp, French photometric standard.

Argand standard lamp.

Photographs of autograph letter of David Melville, the American gas lighting pioneer.

Picture of William Murdoch, the father of the gas industry.

Picture of Phillippe Lebon, the great French inventor.

Picture of F. A. Winsor, pioneer promoter of the gas industry.

Picture of T. S. C. Lowe, inventor of the Lowe water gas apparatus.

Picture of Sir George Livesey, 1834–1908, former chairman, South Metropolitan Gas Company, London.

Photograph of Thomas Dolan, former president of The United Gas Improvement Company.

Picture of Mr. Theobald Forstall, gas engineer.

Picture of A. C. Humphreys, president Stevens Institute of Technology.

Plan of New York City in 1767.

Plan of the city of Philadelphia in 1796.

Picture of historic development of water gas manufacture.

Picture of Lowe water gas apparatus (elevation).

Picture of Lowe water gas apparatus (plan).

Picture of Lowe gas apparatus.

Picture of Lowe gas apparatus.

Picture of Lowe gas apparatus.

Picture of Lowe's improved gas apparatus, S. A. Stevens Company.

Picture of gas machinery of 1881.

Picture of "Early days in the Gas Business."

Picture of "Charging."

Picture of "Warm Work."

Picture of Astoria Plant (New York) first unit coal gas.

Photograph and autograph letter, Dr. Carl Auer von Welsbach.

Framed Paper, Rules of New Orleans Gas Works, by Theobald Forstall.

Old Gas Bill, Philadelphia Gas Works, 1842 (price of gas then $3.50 per thousand).

Old London cartoon, "One of the Advantages of Gas over Oil."

Philadelphia Gas Works prior to 1870.

Three views of Old Philadelphia Gas Works, Market Street and Schuylkill River.

Survey for Philadelphia Gas Works Wharf, 1841.

Volume 1, Number 1, of *The Journal of Gas Lighting*, London, February 10, 1849.

Volume 1, Number 1, of *The American Gas Light Journal*, July 1, 1859.

"Some Information Concerning Gas Lights," by Thomas Cooper, Philadelphia, 1816.

"The Theory and Practice of Gas Lighting," by T. S. Peckston, London, 1819.

Accum's treatise on "The Manufacture of Coal Gas," London, 1820.

Charts of statistics showing the growth of the gas industry.

Loaned by Consolidated Gas Company of New York.

Piece of wooden gas main in use in Long Island City for a number of years.

Model of the home of Mr. Everett, first president of the New York Gas Company, the first house in Manhattan lighted by gas.

Old street lamp meter prior to 1860.

Street lamp meter.

Cavalry sabre blade found in a gas main in Manhattan on making repairs.

Two pictures of wooden gas-holder guide-frame used in Bronx until recent years.

Drawing trunk lines in use in New York from the introduction of gas to the present day.

Full-size drawing of services in use at different periods from the introduction of gas to the present day, ½ inch to 8 inches.

Framed paper—Remonstrance against gas in Philadelphia, 1833.

Eight Consolidated gas bills of different periods from 1827 to 1879.

Five photographs of the air lock used in construction of tunnel for the East River Gas Company of Long Island City.

Three sketches of Old Manhattan Works.

Picture of Manhattan Gas Works, Eighteenth Street Station.

Picture of Manhattan Gas Works, Fourteenth Street Station.

Picture of Metropolitan Gas Works, Sixty-fifth Street and North River.

Picture of Metropolitan Gas Works, Sixty-third and East River.

Picture of Metropolitan Gas Works, Forty-second and North River.

Employees of the Consolidated Gas Company who have been in active service for forty years or more.

Report of Special Committee on Gas Light in 1826.

Photograph of General Office, Irving Place and Fifteenth Street, in 1870.

Picture of proposed Astoria Tunnel showing 2.72-inch pipes.

Picture of entire Street Department of the old New York Gas Company in 1877.

Loaned by New Orleans Gas Light Company.

Check on New Orleans Gas Light and Banking Company by Lee & Hardy, 1836.

List of slaves, showing days worked and days sick of each, 1854.

List of slaves, with gift to each, 1861.

Pen-and-ink drawings in perspective of the New Orleans Gas Works in 1865.

Plan of New Orleans Gas Works, dated 1836.

Picture of Col. W. S. Campbell, engineer, New Orleans Gas Light Company, 1847–1860.

Receipt of State land tax from "The Gas Bank," year 1845.

Promissory Note of New Orleans Gas Light and Banking Company, in 1835, $1,000.

Letter dated 1836, relating to mutual operation between the "New Orleans Gas Light and Banking Company" and a bank in Boston.

Certificate of a survey for the New Orleans Gas Light Company in 1840.

Bond of $15,000 guaranteeing the "Ass't Discount Clerk" of the New Orleans Gas Light and Banking Company, dated 1836.

Paper relating to the sale of a slave to the New Orleans Gas Light Company. The slave is guaranteed against all vices except that of running away, dated 1838.

Night pass for slave, New Orleans Gas Works.

Loaned by Welsbach Company.

The first incandescent gas burner used in America. Received by American Welsbach Company in 1887.

Gordon regenerative lamp, 1884.

Siemens-Lungren regenerative lamp, 1884.

No. 150 Welsbach lamp, made in 1888.

No. 5 Bell burner, June, 1888.

French Welsbach burner, multiple air supply.

Lungren burner, mantle of magnesia, 1887.

Sellon burner, 1887, mantle of platinum gauze (not shown).

Denayrouze Multiple-Bunsen incandescent burner.

No. 3 Welsbach lamp, August, 1888.

No. 75 gas lamp, 1887, made by the Welsbach Company.

Gordon regenerative lamp, 1884.

Loaned by Birkinbine Engineering Offices.

Old drawing for Lebanon Gas Works, 1856.

Old drawing for gas purifying house prior to 1860.

Old drawing for Lock Haven Gas Works, made in the 50's.

Old drawing of Birkinbine patent gas-retort, made about 1860.

Old drawing of Lewisburg Gas Works, made in the 50's.

Old drawing of Lebanon, Pa., Gas Works, 1856.

EXHIBIT.	LOANED BY.
Glazed dry meter, about 1870	Helme & McIlhenny.
Wet meter	Helme & McIlhenny.
Glazed prepayment meter	Helme & McIlhenny.
Meter made in 1863 by John J. Griffin & Co., in New York	John J. Griffin Co., Philadelphia.
Model for column for first gas holder (capacity 250,000 cubic feet) erected for New York Mutual Gas Light Company, 1876	New York Mutual Gas Light Company.
Photograph of building in which gas was first made in Mt. Vernon, New York	Westchester Lighting Company.
Photograph of an old employee	Westchester Lighting Company.
Old gas stove used in Philadelphia prior to 1850	Bartlett & Co., Philadelphia.
Old sun dial stove made in Philadelphia by the Goodwin Company and bought in 1869 by "Uncle Jerry" Howard, of Galena	Eclipse Gas Stove Company.
Consumers' wet meter, 1855, No. 2, made by D. and H. McDonald	D. McDonald & Co., of Albany, N. Y.
Old dry burner test meter square diaphragm, made in the 60's by D. and H. McDonald	D. McDonald & Co., of Albany, N. Y.
Picture of Samuel V. Merrick, engineer of Philadelphia Gas Works	Mr. J. Vaughan Merrick.
Testimonial pitcher awarded to Mr. Samuel V. Merrick, engineer, Old Philadelphia Gas Works, in 1838	Mr. J. Vaughan Merrick.
First gas stock certificate issued in this country	Mr. Julia F. Sachse, librarian, and Committee on Library, Grand Lodge F. & A. M. of Pennsylvania.
A gas bill of fifty years ago, two months, $01 (price of gas then, $10 per thousand)	Savannah Gas Company.

BOOK NOTICES.

PAINT TECHNOLOGY AND TESTS. By Harry A. Gardner, Assistant Director, The Institute of Industrial Research, Washington, D. C.; Director, Scientific Section, Educational Bureau, Paint Manufacturers' Association of the United States, etc. Cloth, 8 vo.; 266 pages. Profusely illustrated. McGraw Hill Book Company, New York. Price, $3.

In this volume Mr. Gardner has collated and systematized the results

obtained from his work on paint technology conducted during the past five or six years for the Paint Manufacturers' Association. This work has covered a wide range of field work, supplemented by extensive physical and chemical research in the laboratory. The information here for the first time set forth in due order of correlation has appeared from time to time in the form of bulletins, reports, and pamphlets to the members of the association, but has not hitherto been available to the general technical public.

In its scope the work covers the technology of the raw materials, laboratory study of the nature and physical characteristics of paint films of varying composition; the testing of paint films *in situ* on various structural material, with details of the field tests conducted for the association; methods of inspecting and reporting such tests, etc. One of the most interesting chapters is that devoted to structural steel paint test, in which the work in connection with Dr. Cushman's theory of inhibition is given in detail. Much of the laboratory methods and devices used are original with the author and are a valuable contribution to the study of paint technology.

G. B. HECKEL.

"GALVANOSTEGIE," Erster Teil, Elektrolytische Metallniederschläge, von Dr. M. S. Schlötter, Band 37 of Monographien uber Angewendte Elektrochemie, 257 pages (24 x 16 cm.). Halle-a.-S., Germany, Wilhelm Knapp. Price, 12 marks.

This book is a scholarly account of the subject of electroplating, in which both patent literature and scientific literature receive adequate treatment. The references to the literature are unusually full for a work of this type. As a whole, the book is a remarkable example of the broad spirit in which the Germans conceive their industrial problems and of the sort of men to whom they intrust the working out of them. It is startling, for instance, to find a "practical" electroplater familiarly invoking the Nernst solution-pressure formula (page 223) to get a quantitative idea of the possibilities when a mechanical mixture of two metals is employed as electrode in a solution containing ions of both. The work is clearly written and requires no previous knowledge of the subject. It will be of the utmost value to every one interested in electroplating.

ROBERT H. BRADBURY.

"TRAITÉ D'ANALYSIS MÈTALLURGIQUES." By J. Hognon. 155 pages (21.5 x 13 cm.). Paris, Gauthier-Villars. Price, 5 francs.

This is an elementary manual of iron and steel analysis, intended especially for works where the basic Bessemer process is in use. The book is written for beginners, and the author wisely refrains from describing too many methods, giving only one, or at most two, for each purpose. These methods are, as a rule, well selected and well described. There are some defects which might be remedied in a second edition.

It seems to the reviewer a mistake to omit all explanation of the calorimetric bomb from the subject of fuel analysis. The naive statement on page 67, that it is possible to pass from a hydrochloric acid solution to a nitric acid solution by simply neutralizing with ammonia and re-acidifying

with nitric acid, is in rather urgent need of revision. The method for the gravimetric determination of sulphur (page 92) should be rewritten, in the light of recent work. On page 96 the author can hardly have intended to advise the chemist to fuse carborundum with a mixture of sodium hydroxide and potassium hydroxide in a platinum crucible. The atomic weight table seems to have been taken, without correction, from some old book. The atomic weight of tin differs from the correct value by a whole unit, while the atomic weight of uranium is given as 240 and that of titanium as 50!

On the whole, the text-book will hardly interest American chemists, since much better works are available in English and in German. There is a table of contents, but no index.

ROBERT H. BRADBURY.

PUBLICATIONS RECEIVED.

Outlines of Applied Optics, by P. G. Nutting, associate physicist, Bureau of Standards, Washington, D. C., Blakiston's Science Series. 234 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1912. Price, in cloth, $2.

Allen's Commercial Organic Analysis, a treatise on the properties, modes of assaying, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufactures, medicines, etc., with concise methods for the detection and estimation of their impurities, adulterations, and products of decomposition. Volume vi. Amines and ammonium bases, aniline and its allies, naphthylamines, pyridine, quinoline, and acridine bases, vegetable alkaloids, volatile bases of vegetable origin, nicotine and tobacco, aconite alkaloids, atropine and its allies, cocaine, opium, strychnos alkaloids, cinchina alkaloids, berberine, caffeine, tea and coffee, cocoa and chocolate, by the editors, and the following contributors: W. H. Glover, R. W. Tonkin, J. J. Fox, Edward Horton, Thomas A. Henry, Francis H. Carr, E. Vanderkleed, P. J. Sageman, Frank O. Taylor, Samuel P. Sadtler, Oliver Chick, R. Whymper. Fourth edition, entirely rewritten. Edited by W. A. Davis and Samuel S. Sadtler. 726 pages, plates, 8vo. Philadelphia, P. Blakiston's Son & Co., 1912. Price, in cloth, $5.

Canada Department of Mines, Mines Branch. An investigation of the coals of Canada, with reference to their economic qualities, as conducted at McGill University, Montreal, under authority of the Dominion Government. In six volumes, by J. B. Porter, E.M., D.Sc., and R. J. Durley, Ma.E., assisted by Théophile C. Denis, B.Sc., Edgar Stansfield, M.Sc., and a staff of special assistants. Vol. i, 233 pages, illustrations, plates, maps, tables, 8vo. Ottawa, Government Printing Bureau, 1912. Price, $1.

Konstant auftretende secundäre Maxima und Minima in den jährlichen Verlauf der meteorologischen Erscheinungen von Dr. Van Rijckevorsel. Sechste abteilung. 39 pages, illustrations, 4to. Rotterdam, W. J. Van Hengel, 1912.

Royal Institution of Great Britain. Weekly evening meeting. May 19, 1911—Recent Experiments with Invisible Light, by Prof. R. W. Wood. 12 pages, plates, 8vo. January 26, 1912—The Pressure of a Blow, by Prof. Ber-

tram Hopkinson, M.A. 15 pages, illustrations, plates, 8vo. February 23, 1912—The Gyrostatic Compass and Practical Application of Gyrostats, by George K. B. Elphinstone, Esq. 5 pages, 8vo. March 1, 1912—The Total Eclipse of the Sun, April, 1911, as observed at Vavau, Tonga Islands, by William J. S. Lockyer, Esq. 13 pages, illustrations, plates, 8vo. March 22, 1912—The North Sea and its Fisheries, by Prof. D'Arcy W. Thompson. 13 pages, 8vo. London, Institution, 1911–12.

U. S. Forest Service. Bulletin No. 106, Wood-using industries and national forests of Arkansas. Part i, Uses and Supply of Wood in Arkansas, by J. T. Harris and Hu Maxwell. Part ii, Timber Resources of the National Forests in Arkansas, by Francis Kiefer. 40 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Mines. First annual report of the Director for the fiscal year ended June 30, 1911. 57 pages, 8vo. Bulletin No. 10, The Use of Permissible Explosives, by J. J. Rutledge and Clarence Hall. 34 pages, illustrations, plates 8vo. Bulletin No. 25, Mining Conditions under the City of Scranton, Pa. Reports and maps by William Griffith and Eli T. Conner, with a preface by Joseph A. Holmes and a chapter by N. H. Darton. 2 vols., illustrations, plates, maps, 8vo. Technical paper 12, The Behavior of Nitroglycerin When Heated, by Walter O. Snelling and C. G. Storm. 14 pages, illustrations, plate, 8vo. Washington, Government Printing Office, 1912.

U. S. Commissioner of Education, Report for the year ended July 30, 1911. Volume i. 675 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Standards. Technologic paper No. 2, The Strength of Reinforced Concrete Beams; Results of Tests of 333 Beams (first series), by Richard L. Humphrey and Louis H. Losse. 200 pages, illustrations, tables, plates. Technologic Paper No. 7, The Testing of Clay Refractories, with Special Reference to Their Load-carrying Capacity at Furnace Temperatures, by A. V. Bleininger, ceramic chemist, and G. H. Brown, assistant ceramic chemist, Bureau of Standards. 78 pages, illustrations, 8vo. Circular No. 33, United States Government Specification for Portland Cement. 28 pages, illustrations, 8vo. Washington, Government Printing Office, 1912.

CURRENT TOPICS

Crop Plants for Paper Making. C. J. BRAND. (*Bureau of Plant Ind. Circular No. 82.*)—The Bureau of Plant Industry is conducting experiments with crop by-products and specially-cultivated plants for paper making. At present the most important crop waste is ordinary Indian-corn stalks, of which 30 million tons are annually available in the corn belt. When extracted with water a ton of corn-stalks yields 200 to 300 pounds of dissolved solids, apparently of high nutritive value, and experiments are now proceeding on feeding stock with the concentrated extract. In addition, the dried stalks yield 12 to 18 per cent. of long fibre of high quality and 15 to 30 per cent. of "pith-pulp" of less value but utilizable in special directions. "Broom-corn" stalks look more promising both as regards yield and quality, but the production is only estimated at 450,000 tons. The proportion of pith in the "broom-corn" stalk is not so large, and pulp may be used up to 50 per cent. in the composition of high-class book paper without any separation of the pith-cells, which is absolutely necessary with ordinary corn-stalks. Rice straw is one of the most promising of raw materials; about 1½ million tons is the estimated product. It is expected to yield about 35 per cent. of pulp suitable for excellent qualities of book paper. Cotton hull fibre has already established itself as an industrial raw material of considerable value. Cotton stalks and bagasse do not appear likely to yield satisfactory substitutes for wood pulp. About 3 million tons of flax straw are produced, of which about 300,000 tons are utilized for the manufacture of a rough grade of tow. Hemp is perhaps the most attractive crop which could be grown, from the point of view of paper making. It should be "dew-retted" to avoid impoverishing the soil. One acre should yield 2½ to 3 tons of retted stalks, yielding 40 to 45 per cent. of pulp.

Normal Light Mercury-vapor Lamps. (*Engineering*, xcii, No. 2400, 873.)—Mr. Cooper Hewitt has recently succeeded in improving his mercury-vapor lamps by turning their ghastly bluish-green light into a normal light, white with a trace of pink. Various attempts were made to supply the deficient red rays. The tubes were charged with nitrogen, the rays appeared pink when plunged in ice, but the regular tint reappeared at ordinary temperature. Argon and helium behaved similarly. Herœus used an amalgam containing 20 per cent. lead and 20 per cent. bismuth, with about 0.5 per cent. each of zinc and cadmium; but these alloys and others containing thallium and antimony practically yielded mercury arcs. Then Mr.

Hewitt tried combining a mercury arc with an incandescent carbon filament, but these complicated lamps became inefficient. He then turned to fluorescence and was successful with fluorescent screens. Mercury arc tubes surrounded with gauze veils dyed with rhodamine were first applied, but the efficiency was poor and the light was unpleasant. Then rhodamine reflectors were placed behind the mercury tubes and a pleasant light was produced. But, unfortunately, rhodamine is not fast to light, and the screen lost its effectiveness in about 24 hours. Hence it became necessary to incorporate the rhodamine with some substance which would render it more durable without interfering with the fluorescence. Such a substance has recently been found, and the paper screens are now coated with rhodamine by a complicated process. It is claimed that objects appear of the same tint, when examined in daylight, as they do in the light of these new mercury arcs fitted with rhodamine reflectors. Mr. Hewitt's patent describes this as a varnish consisting of 70 parts of cellulose acetate, 10 parts of glycerin, and 20 parts of acetic acid, dissolved in pure acetone to form a 12 per cent. solution, to which a quantity of rhodamine equal to 3 per cent. of the weight of cellulose acetate and glycerin is added.

Deterioration and Spontaneous Heating of Coal in Storage. H. C. PORTER and F. K. OVITZ. (*J. Ind. Eng. Chem.*, iv, 5.)—This investigation was conducted by the United States Bureau of Mines. With New River Coal, which is largely used by the United States Navy, there was a loss of less than 1 per cent. in calorific value (calculated to "coal substance free of moisture, sulphur, and corrected ash") when a 300-pound sample was exposed in the open air for 1 year. There was practically no loss in samples submerged in sea water or in fresh water. Pocahontas "run of mine" coal, a steaming and coking coal, which is the principal fuel used in the Panama Canal work, lost less than 0.4 per cent. in calorific value by exposure for one year. Pittsburgh coal, a rich coking and gas coal, suffered no loss in calorific value by exposure for 6 months. Wyoming coal, a sub-bituminous coal or black "lignite," lost 5.3 per cent. of its calorific value in 2¾ years, and as much as 3.5 per cent. during the first three months' exposure. Storage under water prevents loss of calorific value, and, as it also prevents spontaneous combustion, may be advantageously adopted in some cases; but there is the great disadvantage that some kinds of coal retain a large proportion of water after draining, and fuel would be consumed to evaporate this water. With regard to the spontaneous combustion of coal, these suggestions are made: (1) Coal should not be piled more than 12 feet deep, nor so that any point in the interior will be more than 10 feet from an air-cooled surface. (2) If possible, lumps only should be stored. (3) Handling of the coal should be reduced to a minimum to avoid making dust. (4) Lumps and fines should be

distributed in the pile as evenly as possible, taking care the lumps do not roll down and form air passages at the bottom. (5) The coal should be rehandled and screened after two months. (6) External sources of heat should not be allowed near the pile. (7) Coal, after mining, should be "seasoned" for 6 weeks before storing in piles. (8) Alternate wetting and drying of the coal should be avoided. (9) Admission of air to the interior of the pile through interstices or porous foundations should be avoided. (10) Ventilation by pipes should not be attempted.

Lighting by Neon Tubes. (*Engineering*, xcii, No. 2398, 807.)—As has long been known, a vacuum tube charged with neon gives a brilliant light with but little absorption of electric energy, yet there is a progressive absorption of the gas and the light is finally extinguished. M. G. Claude described a number of experiments made to overcome this. He found that when the tubes had small electrodes, these heated rapidly nearly to redness, and a metallic deposit formed on the glass in their vicinity. After 88 hours this deposit amounted to 1.6 gramme. On examination neon was found occluded in the metal. Hence, as the disappearance of the gas was due to the vaporization of the metal, M. Claude reasoned that the life of the tube would be lengthened by using larger electrodes, which would keep cooler. He constructed a neon tube, 45 mm. in diameter, with copper electrodes equivalent to a surface of 300 sq. cm. per ampère of current. One of these tubes worked satisfactorily for 210 hours and was then accidentally broken. Since then, with a tube 6 metres long, with electrodes giving a surface of 500 sq. cm. per ampère, M. Claude found that the potential difference necessary to maintain the current only changed 4 per cent. in 400 hours. The efficiency was excellent, only 0.8 watt per candle. It is interesting to note that were the energy wholly convertible into that light to which the eye is most sensitive, the output would be 55 candles per watt, according to recent measurements by MM. H. Buisson and Ch. Fabry.

"Corubin," a New Abrasive. ANON. (*Metal Ind.*, x, 2, 82.)—"Corubin" is a new abrasive manufactured abroad. It is produced from the slag resulting from the reaction between aluminum and chromium oxides. It is practically pure alumina, containing a trace of chromium oxide, which gives it a red color. On account of the high temperature at which it is manufactured it is free from combined water. It is produced in three grades—coarse, medium, and fine—and is sold only in the proportion of two parts coarse to one each of medium and fine.

Monel Metal. ANON. (*The Metal Ind.*, x, 2, 72.)—Monel metal is now to be had in the form of wire at a cost that compares

favorably with high-grade German silver, but the properties of this new wire are of such high order that it should not be confused with numerous white metals of German or nickel silver. Tests have shown that this monel wire is as strong as steel wire, while it is less corrodible than copper and takes a finish like pure nickel. Electrical tests have shown that Monel wire has the following properties:

Electrical resistivity—256 ohms per mil-foot. (Temp. coefficient, .0011 per 1° F.

Electrical conductivity, 4 per cent. (copper 100 per cent.).

Pure Vanadium. O. RUFF and W. MARTIN. (*Zeit. Angew. Chem.*, XXV, 49.)—The starting-point was the difficulty fusible vanadium trioxide; the more readily fusible pentoxide was found to be unsuitable. The alumino-thermic method, when carbon was substituted for a portion of the theoretically necessary aluminum, yielded a product containing from 95 to 99 per cent. of vanadium. Equally good results were obtained by making rods of the trioxide mixed with sugar charcoal, and heating them, first to sintering in Ruff's electrical vacuum resistance furnace, then to fusion in an arc furnace; or by melting down in zirconia crucibles at a temperature of about 2000° C. a mixture of vanadium carbide and trioxide. The carbide was obtained by fusing a suitable mixture of trioxide and carbon in a carbon crucible in a Ruff furnace at 2800° C. Pure vanadium melts at 1715° C.; its specific gravity, at 18.7° C., is 5.688; the heat of combustion of 1 gramme to V_2O_5 is 2456 calories. The melted metal readily dissolves both the trioxide and the carbide; and these mixtures melt at a higher temperature than the metal. The trioxide melts at 2000° C.; the carbide at 2750° C.

Explosion of Radium Bromide. B. JOST. (*Chem. Zeit.*, XXXVI, 138.)—In several instances small grains of radium bromide burst into minute particles with explosive violence in the spinthariscope or in the air when the salt was transferred by means of a moistened needle. The phenomenon was only observed in the case of a very pure and old salt, and when traces only of water were present.

NOTES FROM THE BUREAU OF STANDARDS.

THERMOMETRIC LAG.

1. THERMOMETRIC lag is conveniently expressed by employing a quantity λ, whose significance may be stated as follows:

(*a*) If a thermometer has been immersed for a long time in a bath whose temperature is rising at a uniform rate, λ is the number of seconds between the time when the bath attains any given temperature and the time when the thermometer indicates this temperature. In other words, it is the number of seconds the thermometer "lags" behind the temperature.

Or[1]

(*b*) If a thermometer be plunged into a bath maintained at a constant temperature (the thermometer being initially at a different temperature), λ is the number of seconds in which a difference between the thermometer reading and bath temperature is reduced to $1/e$ of its initial value.

The fundamental equation of heat transfer, commonly referred to as Newton's law of cooling, is stated in terms of λ, for application to problems in thermometric lag, and the principal working equations derived therefrom are reviewed.

2. To express analytically the lag of the common form of Beckmann thermometer, the simpler theory was modified to take into account the fact that the lag of the bulb and that of the large capillary between the bulb and the fine capillary are different.

3. Methods of determining lag are discussed and experiments are cited to test the theories as applied to ordinary "chemical" thermometers and to Beckmann thermometers.

4. The large variation in the lag of a given thermometer with the nature of the medium in which it is immersed, and with the rate of stirring of this medium, is brought out by experiments in water, in a viscous kerosene, and in air, in which these media were forced past the bulb of the thermometer at different measured rates.

[1] These two interpretations of λ are mutually consistent. The actual definition of the quantity is most logically made by designating it as the "constant" of the fundamental equation, and then deducing the interpretations here given.

Values from the curves obtained here:

λ IN SECONDS. SMALL BULB "CHEMICAL" THERMOMETER.

Vel. past bulb in cm./sec.	0	1	5	10	50	100	500	1000	∞
Water.....	10.0	5.1	3.3	2.9	2.4	2.3	——	——	2.2 seconds (any medium)
Oil.....	40 to 50	13.4	7.5	6.4	4.8	——	——	——	
Air.....	190.	170.	148.	128.	71.	58.	33	25	

5. Part, and frequently the largest part, of the lag of a thermoelectric or electrical resistance thermometer is the lag of the galvanometer. A d'Arsonval galvanometer, critically damped, is shown to lag $4 \times \frac{\text{Moment of Inertia of Moving System}}{\text{Damping coefficient}}$ seconds behind and e.m.f. changing linearly with time, after the steady state of motion is attained. A close approximation to this value is lag $= T/\pi$ seconds, where T is the complete period of the moving system, oscillating much underdamped.

6. Types of resistance thermometers were tested for lag. The Callendar type, in a liquid bath, was found to lag greatly in comparison with an ordinary "chemical" mercurial thermometer, and the empirical expression of the lag of the same form as that developed for a Beckmann thermometer. The Dickinson-Mueller type of resistance thermometer bulb in a liquid bath was found to lag much less than the fastest of mercurial thermometers.

7. The Jaeger-Steinwehr method of computing the lag of a resistance thermometer, from the heating effect of the measuring current and the heat capacity of the thermometer, is critically discussed. The lag of a Dickinson-Mueller thermometer in a well-stirred liquid bath is shown to be about one-half second.

8. The necessary corrections that must be applied to the observed readings of a thermometer, to correct for the effect of its lag, under the usual conditions of use, are discussed in some detail.

9. An analytic proof is given of the fact that in an ordinary calorimetric experiment, in which the same thermometer is used to determine temperatures in the "pre-period," the "middle period," and the "after period," the correction for lag in the middle period neutralizes the corrections for lag in the pre-period and the after period.

WASHINGTON, February, 1912.

ABSTRACT TECHNOLOGIC PAPER NO. 9, THE BUREAU OF STANDARDS.

BY

H. W. Bearce,

Assistant Physicist.

SIXTEEN samples of linseed oil of known origin and purity were tested. A complete history of these samples is given in Technologic Paper No. 9, Bureau of Standards, and also in the 1911 *Proceedings of the American Society for Testing Materials.* Six samples of gum turpentine, three samples of wood turpentine, two samples of "wood spirits," and one sample of "oil" of turpentine were also tested.

The density of each sample was determined at 10°, 20°, 30°, and 40° C. by the method of hydrostatic weighing. Special apparatus was employed by means of which any turpentine between 10° and 40° C. could be obtained and automatically maintained sensibly constant for any desired length of time. The densities were determined by weighing in the sample at each temperature a plummet or sinker of known mass and volume, the sinker having been calibrated by weighing in twice-distilled water.

The temperatures were read on two mercurial thermometers suspended in a glass tube placed parallel and adjacent to the tube containing the sample.

The sinker used in the density determinations was of Jena 16 III glass, ballasted with mercury, and had approximately the following dimensions: length, 30 cm.; diameter, 15 cm.; volume, 50 c.c.; mass, 100 g.

In making a density determination the method of procedure was as follows: The water in the outside bath was brought to the desired temperature by proper adjustment of the heating and cooling coils. After sufficient time had elapsed to allow the apparatus to attain temperature equilibrium, observations were begun. First, a weighing was made with the sinker suspended in the liquid, then the two thermometers were read; next, a tare weighing was made with the suspension wire still passing through the surface of the liquid, but with the sinker detached and resting on the bottom of the containing tube; then a second weighing with the sinker attached, and after that a second reading of the thermometers.

After completing the observations on a sample at the four temperatures 10°, 20°, 30°, and 40° C., the density at each temperature was calculated by means of the equation

$$D_t = \frac{W - \frac{(w-w_1)+(w-w_2)}{2}\left(1-\frac{\rho}{8.4}\right)}{V_t}$$

In which D_t = density of sample at temp. t. (in gms/ml).
W = weight of sinker in vacuo.
w = weighing with sinker off.
w_1 and w_2 = weighing with sinker on.
ρ = air density.
8.4 = assumed density of brass weights.
V_t = volume of sinker at temp. t.

After calculating the density at each temperature, a least squares reduction was applied to the calculated results in order to find the most probable value of the density at each temperature. It was assumed that the equation $Dt = D + \alpha(t - x) + \beta(t - x)^2$ represents sufficiently well the rate of expansion. The very small residuals obtained show that the assumption was justified.

A summary of the results of the investigation is here given.

SUMMARY OF RESULTS

TABLE I

THE DENSITY AND THERMAL EXPANSION OF LINSEED OIL AT TEMPERATURES BETWEEN 10° AND 40° C.

Sample No.	$D\frac{10°}{4°}C$	$D\frac{20°}{4°}C$	$D\frac{30°}{4°}C$	$D\frac{40°}{4°}C$	$D\frac{25°}{4°}C$	$\alpha \times 10^7$	$\beta \times 10^9$
5	.93 513	.92 823	.92 139	.91 460	.92 480	−6844	+262
16	.93 526	.92 841	.92 158	.91 475	.92 499	−6836	+ 50
13	.93 561	.92 875	.92 193	.91 514	.92 534	−6823	+192
2	.93 598	.92 911	.92 226	.91 543	.92 568	−6851	+ 90
11	.93 606	.92 920	.92 235	.91 552	.92 578	−6848	+ 58
3	.93 614	.92 928	.92 244	.91 561	.92 586	−6843	+ 90
12	.93 624	.92 938	.92 255	.91 573	.92 596	−6838	+ 95
6	.93 668	.92 981	.92 295	.91 611	.92 638	−6857	+110
14	.93 704	.93 016	.92 329	.91 642	.92 672	−6875	+ 38
8	.93 710	.93 022	.92 338	.91 657	.92 680	−6843	+168
7	.93 716	.93 031	.92 347	.91 664	.92 688	−6840	+ 78
4	.93 738	.93 049	.92 365	.91 686	.92 706	−6842	+240
9	.93 746	.93 062	.92 377	.91 691	.92 720	−6850	− 88
15	.93 755	.93 063	.92 378	.91 699	.92 720	−6852	+320
10	.93 761	.93 073	.92 389	.91 707	.92 730	−6844	+155
1	.93 789	.93 100	.92 413	.91 727	.92 756	−6873	+ 78
Mean					92 634	−6847	+120

$$D_t = D_{25} + \alpha (t-25) + \beta(t-25)^2 \quad (1)$$

Taking for α and β the mean values of the 16 samples the general equation becomes $D_t = D_{25} - 0.000\ 6847(t-25) + 0.000\ 000\ 12(t-25)^2$. If it is desired to reduce the expansion to a single term for use over a short temperature range, this may be done by differentiating the general equation and combining α and β into a single term, α^1, which will be different for different temperatures.

$$D_t = D_{25} + \alpha (t-25) + \beta(t-25)^2$$

$$\frac{dD_t}{dt} = \alpha + 2\beta(t-25) = \alpha^1 \quad (2)$$

Substituting for t the values 10, 15, 20, 25, 30, 35, and 40, gives for the rate of change of density at the different temperatures the following values:

Temperature. ° C.	Change per degree C.
10	0.000 688 3
15	.000 687 1
20	.000 685 9
25	.000 684 7
30	.000 683 5
35	.000 682 3
40	.000 681 1

The results obtained from the six samples of gum turpentine shown in Group I were used in the calculation of Table IV for determining the density of turpentine at various temperatures.

If the general equation $D_t = D_{25} + \alpha (t-25) + \beta(t-25)^2$ be differentiated and the mean values of α and β substituted in the first derivative the change of density per degree at different temperatures is seen to be as shown below.

$$D_t = D_{25} + \alpha (t-25) + \beta (t-25)^2$$

$$\frac{d D_t}{dt} = \alpha + 2\beta (t-25) = \text{change of density per degree} = \alpha^1$$

t	α^1
10	.000 814 2
15	815 1
20	816 1
25	817 0
30	817 9
35	818 9
40	819 8

In calculating Table IV these values of α^1 were taken as the rate of change of density of turpentine having a density of 0.8640 at 20° C. (this being the mean of the six samples from

TABLE II

DENSITY AND THERMAL EXPANSION OF TURPENTINE AT TEMPERATURES BETWEEN 10° AND 40° C.

Sample No.	$D^{10°}_{4°C}$	$D^{20°}_{4°C}$	$D^{30°}_{4°C}$	$D^{40°}_{4°C}$	$D^{25°}_{4°C}$	$a \times 10^7$	$\beta \times 10^9$	Refractive index at 27 °C.	Optical rotation at 25 C°.	Remarks.
									°	
3	0.86 932	0.86 124	0.85 314	0.84 500	0.85 719	−8104	−150	1.4671	− 8.6	Group I, gum turpentines.
7	.86 988	.86 174	.85 357	.84 539	.85 766	−8165	− 95	1.4673	+15.9	
2	.87 211	.86 394	.85 574	.84 752	.85 984	−8195	−105	1.4710	− 7.2	
8	.87 256	.86 440	.85 623	.84 804	.86 032	−8174	− 55	1.4670	+12.7	
12	.87 393	.86 576	.85 756	.84 933	.86 166	−8198	−148	1.4672	+ 4.3	
1	.87 468	.86 649	.85 831	.85 012	.86 240	−8186	− 8	1.4784	+14.4	
Mean						−8170	− 94			
9	.86 988	.86 165	.85 341	.84 516	.85 753	−8242	− 55	1.4636	+22.9	Group II, wood turpentine steam distilled.
10	.87 024	.86 205	.85 384	.84 559	.85 795	−8214	−160	1.4656	+17.7	
4	.87 229	.86 406	.85 571	.84 724	.85 990	−8350	−580	1.4648	+26.3	
Mean						−8269	−265			
5	.87 380	.86 456	.85 547	.84 626	.86 006	−9181	−130	1.4594	+ 4.7	Group III, wood "spirits" destructively distilled.
6	.87 606	.86 693	.85 775	.84 852	.86 235	−9181	−258	1.4613	+ 4.7	
11	.95 518	.94 728	.93 930	.93 123	.94 330	−7986	−428	1.4789	0.0	"Oil" of turpentine.

which $\propto^1$ was derived). For turpentine having a density at 20° either greater or less than 0.8640 $\propto^1$ was calculated from mean $D\frac{20°}{4°}$ and mean $\propto^1$ of the three lightest samples and mean $\frac{D20°}{4°}$ and mean $\propto^1$ of the three heaviest samples.

TABLE III

DENSITY OF LINSEED OIL AT ANY TEMPERATURE BETWEEN 10° AND 40° C. FROM ITS DENSITY AT 20° C.

	Density at 20° C. (in grams per milliliter).						
	0.9260	0.9270	0.9280	0.9290	0.9300	0.9310	0.9320
Required temperature.	Density at required temperature.						
°C.							
10	0.9329	0.9339	0.9349	0.9359	0.9369	0.9379	0.9389
11	.9322	.9332	.9342	.9352	.9362	.9372	.9382
12	.9315	.9325	.9335	.9345	.9355	.9365	.9375
13	.9308	.9318	.9328	.9338	.9348	.9358	.9368
14	.9301	.9311	.9321	.9331	.9341	.9351	.9361
15	.9294	.9304	.9314	.9324	.9334	.9344	.9354
16	.9288	.9298	.9308	.9318	.9328	.9338	.9348
17	.9281	.9291	.9301	.9311	.9321	.9331	.9341
18	.9274	.9284	.9294	.9304	.9314	.9324	.9334
19	.9267	.9277	.9287	.9297	.9307	.9317	.9327
20	.9260	.9270	.9280	.9290	.9300	.9310	.9320
21	.9253	.9263	.9273	.9283	.9293	.9303	.9313
22	.9246	.9256	.9266	.9276	.9286	.9296	.9306
23	.9239	.9249	.9259	.9269	.9279	.9289	.9299
24	.9233	.9243	.9253	.9263	.9273	.9283	.9293
25	.9226	.9236	.9246	.9256	.9266	.9276	.9286
26	.9219	.9229	.9239	.9249	.9259	.9269	.9279
27	.9212	.9222	.9232	.9243	.9252	.9262	.9272
28	.9205	.9215	.9225	.9235	.9245	.9255	.9265
29	.9198	.9208	.9218	.9228	.9238	.9248	.9258
30	.9192	.9202	.9212	.9222	.9232	.9242	.9252
31	.9185	.9195	.9205	.9215	.9225	.9235	.9245
32	.9178	.9188	.9198	.9208	.9218	.9228	.9238
33	.9171	.9181	.9191	.9201	.9211	.9221	.9231
34	.9164	.9174	.9184	.9194	.9204	.9214	.9224
35	.9157	.9167	.9177	.9187	.9197	.9207	.9217
36	.9150	.9160	.9170	.9180	.9190	.9200	.9210
37	.9144	.9154	.9164	.9174	.9184	.9194	.9204
38	.9137	.9147	.9157	.9167	.9177	.9187	.9197
39	.9130	.9140	.9150	.9160	.9170	.9180	.9190
40	.9123	.9133	.9143	.9153	.9163	.9173	.9183

TABLE IV

DENSITY OF TURPENTINE AT ANY TEMPERATURE BETWEEN 10° AND 40° C. FROM ITS DENSITY AT 20° C.

	Density at 20° C. (in grams per milliliter).															
	0.8550	0.8560	0.8570	0.8580	0.8590	0.8600	0.8610	0.8620	0.8630	0.8640	0.8650	0.8660	0.8670	0.8680	0.8690	0.8700
Required temperature °C	Density at required temperature.															
10	0.8631	0.8641	0.8651	0.8661	0.8671	0.8681	0.8691	0.8701	0.8711	0.8722	0.8732	0.8742	0.8752	0.8762	0.8772	0.8782
11	.8623	.8633	.8643	.8653	.8663	.8673	.8683	.8693	.8703	.8713	.8724	.8734	.8744	.8754	.8764	.8774
12	.8614	.8625	.8635	.8645	.8655	.8665	.8675	.8785	.8695	.8705	.8715	.8725	.8735	.8746	.8756	.8766
13	.8606	.8616	.8627	.8637	.8647	.8657	.8667	.8677	.8687	.8697	.8707	.8717	.8727	.8737	.8747	.8758
14	.8598	.8608	.8618	.8639	.8639	.8649	.8659	.8669	.8679	.8689	.8699	.8709	.8719	.8729	.8739	.8749
15	.8590	.8600	.8610	.8620	.8630	.8641	.8651	.8661	.8671	.8681	.8691	.8701	.8711	.8721	.8731	.8741
16	.8582	.8592	.8602	.8612	.8622	.8632	.8642	.8652	.8663	.8673	.8683	.8693	.8703	.8713	.8723	.8733
17	.8574	.8584	.8594	.8604	.8614	.8624	.8634	.8644	.8654	.8664	.8674	.8684	.8695	.8705	.8715	.8725
18	.8566	.8576	.8586	.8596	.8606	.8616	.8626	.8636	.8646	.8656	.8666	.8676	.8686	.8696	.8706	.8716
19	.8558	.8568	.8578	.8588	.8598	.8608	.8618	.8628	.8638	.8648	.8658	.8668	.8678	.8688	.8698	.8708
20	.8550	.8560	.8570	.8580	.8590	.8600	.8610	.8620	.8630	.8640	.8650	.8660	.8670	.8680	.8690	.8700
21	.8542	.8552	.8562	.8572	.8582	.8592	.8602	.8612	.8622	.8632	.8642	.8652	.8662	.8672	.8682	.8692
22	.8534	.8544	.8554	.8564	.8674	.8584	.8594	.8604	.8614	.8624	.8634	.8644	.8654	.8664	.8674	.8684
23	.8526	.8536	.8546	.8556	.8566	.8576	.8586	.8596	.8606	.8616	.8626	.8636	.8645	.8655	.8665	.8675
24	.8518	.8528	.8538	.8548	.8558	.8568	.8578	.8587	.8597	.8607	.8617	.8627	.8637	.8647	.8657	.8667
25	.8510	.8520	.8530	.8540	.8549	.8559	.8569	.8579	.8589	.8599	.8609	.8619	.8629	.8639	.8649	.8659
26	.8502	.8512	.8521	.8531	.8541	.8551	.8561	.8571	.8581	.8591	.8601	.8611	.8621	.8631	.8641	.8651
27	.8493	.8503	.8513	.8523	.8533	.8543	.8553	.8563	.8573	.8583	.8593	.8603	.8613	.8623	.8632	.8642
28	.8485	.8495	.8505	.8515	.8525	.8535	.8545	.8555	.8565	.8575	.8585	.8594	.8604	.8614	.8624	.8634
29	.8477	.8487	.8407	.8507	.8517	.8527	.8537	.8547	.8557	.8566	.8576	.8586	.8596	.8606	.8616	.8626
30	.8469	.8479	.8489	.8499	.8509	.8519	.8529	.8538	.8548	.8558	.8568	.8578	.8588	.8598	.8608	.8618
31	.8461	.8471	.8481	.8491	.8501	.8510	.8520	.8530	.8540	.8550	.8560	.8570	.8580	.8590	.8600	.8610
32	.8453	.8463	.8473	.8483	.8492	.8502	.8512	.8522	.8532	.8542	.8552	.8562	.8572	.8582	.8591	.8601
33	.8445	.8455	.8465	.8474	.8484	.8494	.8504	.8514	.8524	.8534	.8544	.8554	.8563	.8573	.8583	.8593
34	.8437	.8447	.8456	.8466	.8476	.8486	.8496	.8506	.8516	.8526	.8535	.8545	.8555	.8565	.8575	.8585
35	.8429	.8438	.8448	.8458	.8468	.8478	.8488	.8498	.8508	.8517	.8527	.8537	.8547	.8557	.8567	.8576
36	.8421	.8430	.8440	.8450	.8460	.8470	.8480	.8490	.8499	.8509	.8519	.8529	.8539	.8459	.8558	.8568
37	.8412	.8422	.8432	.8442	.8452	.8462	.8472	.8481	.8491	.8501	.8511	.8521	.8530	.8540	.8550	.8560
38	.8404	.8414	.8424	.8434	.8444	.8454	.8463	.8473	.8483	.8493	.8503	.8512	.8522	.8532	.8542	.8552
39	.8396	.8406	.8416	.8426	.8435	.8445	.8455	.8465	.8475	.8485	.8494	.8504	.8514	.8524	.8534	.8544
40	.8388	.8398	.8408	.8418	.8427	.8437	.8447	.8457	.8467	.8476	.8486	.8496	.8506	.8516	.8526	.8535

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